THE ECOLOGY OF STEWART ISLAND

FRESHWATER COMMUNITIES

A thesis

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ABSTRACT

A comprehensive survey of the stream and river faunas of Stewart Island (invertebrates and fish) was undertaken between August 1987 and December 1989. In total, 113 invertebrate taxa and 12 fish species were recorded. The invertebrate fauna is characterised by a common core of taxa (*Chiltonia rivertonensis*, Oligochaeta, Chironomidae, *Deleatidium*, *Zelandoperla*, *Zelandobius*, *Austroperla cyrene*, *Hydrobiosella stenocerca*, Hydrobiosidae, Simuliidae, and Scirtidae) and a paucity or absence of some common mainland families or genera, notably the Notonemouridae, Conoesucidae, and *Archichauliodes*. The fish fauna consists of diadromous species except for *Galaxias vulgaris*. A number of invertebrate and fish species are more widespread, or abundant, and occupy more diverse habitat types than reported in mainland studies. They include the isopod *Austridotea benhami*, and the fishes *Galaxias argenteus*, *G. fasciatus* and *Gobiomorphus huttoni*. These differences may reflect the more pristine conditions of Stewart Island streams and an absence of predatory salmonids on the island.

Gut analysis of *G. huttoni* and *G. fasciatus* confirmed that they fed predominantly on benthic invertebrates and terrestrial prey items, respectively. Both species appeared to be opportunistic feeders and showed a low degree of prey selectivity.

Experimental studies at six sites in the Rakeahua River system indicated that leaf litter breakdown (kamahi leaves) rates were rapid at headwater sites where feeding by shredders (principally *Austroperla cyrene*) was high. In contrast, breakdown rates were slower at mainstem sites even though the large detritivore/carnivore, *Austridotea benhami* was present.

In summary, the Stewart Island freshwater fauna can be seen to possess a number of distinctive features, but the extent of these appear to be no greater than those found between the North and South Islands of New Zealand. Stewart Island is unique, however, because of the apparent absence of adventive species, including trout, that are common on the mainland. Because of this and the largely pristine nature of its catchments, I suggest that greater protection should be afforded to the island's freshwater systems than is imparted by Reserve and Conservation Land status.

CHAPTER 1

GENERAL INTRODUCTION

In many parts of the world where a surplus of water exists, streams have often been viewed as 'drains' for the removal of excess water, to carry away effluents, or to impound for hydroelectricity (Peterson *et al.* 1987). Consequently, their ecological importance has frequently been neglected. With the growing awareness of environmental values, society is now requiring water and land managers to move away from exploitation of streams and their catchments to a state of guardianship (Barmuta 1989). This changing role must ultimately lead to decisions about conservation and eventually restoration or rehabilitation of certain river systems. In New Zealand, implementation of such strategies is hampered by a dearth of knowledge, particularly of the biology of pristine, lowland streams, as most now represent highly modified environments (Winterbourn 1987). This is a consequence of human settlement, urbanisation, or rural development, and has involved channelisation, enrichment of ground and surface waters, and the introduction of exotic plants and animals including predatory salmonid fishes. There is now a very real need for studies of pristine river systems in New Zealand to ensure that stream classification, the first step towards implementation of a conservation or guardianship strategy (Barmuta 1989), can fully take into account pre-disturbance conditions.

One area that is relatively free from human disturbance and faunal and floral introductions is Stewart Island. Much of the lowland forest is intact, trout are unrecorded and other introduced fishes appear to have been absent, at least until recently.

The freshwater fauna is poorly known, however, and McDowall (1987) noted records for only four native fish species on the island. Also, apart from some records in primarily taxonomic papers (e.g. Simuliidae, Dumbleton 1973; *Rakiura vernale*, McFarlane 1973, Michaelis 1973; various other Trichoptera, McFarlane and Cowie 1981), and a limited survey of predominantly sandy bottomed streams and bogs in the lower Freshwater Valley (Cowie *et al.* 1978), the benthic invertebrate fauna is largely unknown.

The primary objective of my study was to make a comprehensive description of the lotic freshwater fauna (invertebrate and fish) of Stewart Island and to determine whether it included distinctive features. Invertebrate and fish faunas were surveyed in streams throughout the island to obtain information on community composition, relative abundance, geographic distributions and habitats. In addition to this survey based work, two more specific studies were incorporated in the program. In the first of these, the diets of two of the most common fish, banded kokopu (*Galaxias fasciatus*) and red finned bully (*Gobiomorphus huttoni*) were examined in the Maori and Rakeahua Rivers, respectively, and compared with the findings of mainland, New Zealand studies (McDowall 1965a, Main 1988, Main and Lyon 1988). In the second, breakdown and macroinvertebrate colonisation of kamahi leaves, (a major input to streams) was investigated at six sites on the Rakeahua River and compared with the work of Collier (1988) in small, South Westland streams.

CHAPTER 2

GENERAL DESCRIPTION AND HISTORY OF STEWART ISLAND

INTRODUCTION

Stewart Island or Rakiura (Fig. 2.1) is the smallest (1683 km^2) and southernmost (47°S 168° E) of the three main islands of New Zealand, and the only one to remain relatively unmodified by human occupation (Wilson 1987). The island was occupied by Polynesians at least intermittently for 700 years or more (Wilson 1987), and since the mid 1800's European settlers have exploited a variety of the island's natural resources to a limited extent.

As early as the 13^{th} century, Stewart Island was believed to have been visited by moa hunters, principally on food gathering trips. Muttonbirds, oysters, eels and possibly moa were collected. Upon the arrival of Europeans, the main pa was situated on Ruapuke Island in Foveaux Strait, and small outlying villages were present at Port William, The Neck, Port Adventure, and possibly lower Freshwater Valley (Fig. 2.1). There is also evidence of early Maori settlements at Mason Bay, East Ruggedy, Codfish Island, Horseshoe Bay, and Native Island (Piper 1961). All these settlements were thought to have been small and temporary, and the activities of their inhabitants probably had little impact on the surrounding countryside.

The first Europeans to settle Stewart Island were sealers in the early 1800's. Their dwellings were temporary and wrought little change on the landscape. By 1810, the numbers of seals and sealers had begun to decline and after a brief resurgence in the 1920s, most sealers left. A few took Maori wives and settled on Codfish Island.

From 1830 to about 1880, whaling replaced sealing on the surrounding seas. However, Stewart Island was never used as a whaling base, although a trying out base was establish at Port Pegasus for a time. A Norwegian company established a refitting base and coaling depot at Kaipipi in the early 1920s, but it was abandoned in 1932.

From the mid 1860s, a succession of extraction industries attracted small settlements of Europeans. These were little more than collections of shacks built in clearings in the "bush" and were never located far from the sea. Timber, mainly rimu and totara, was milled from 1861, but ceased in 1931 when easily accessible supplies ran out. Although the

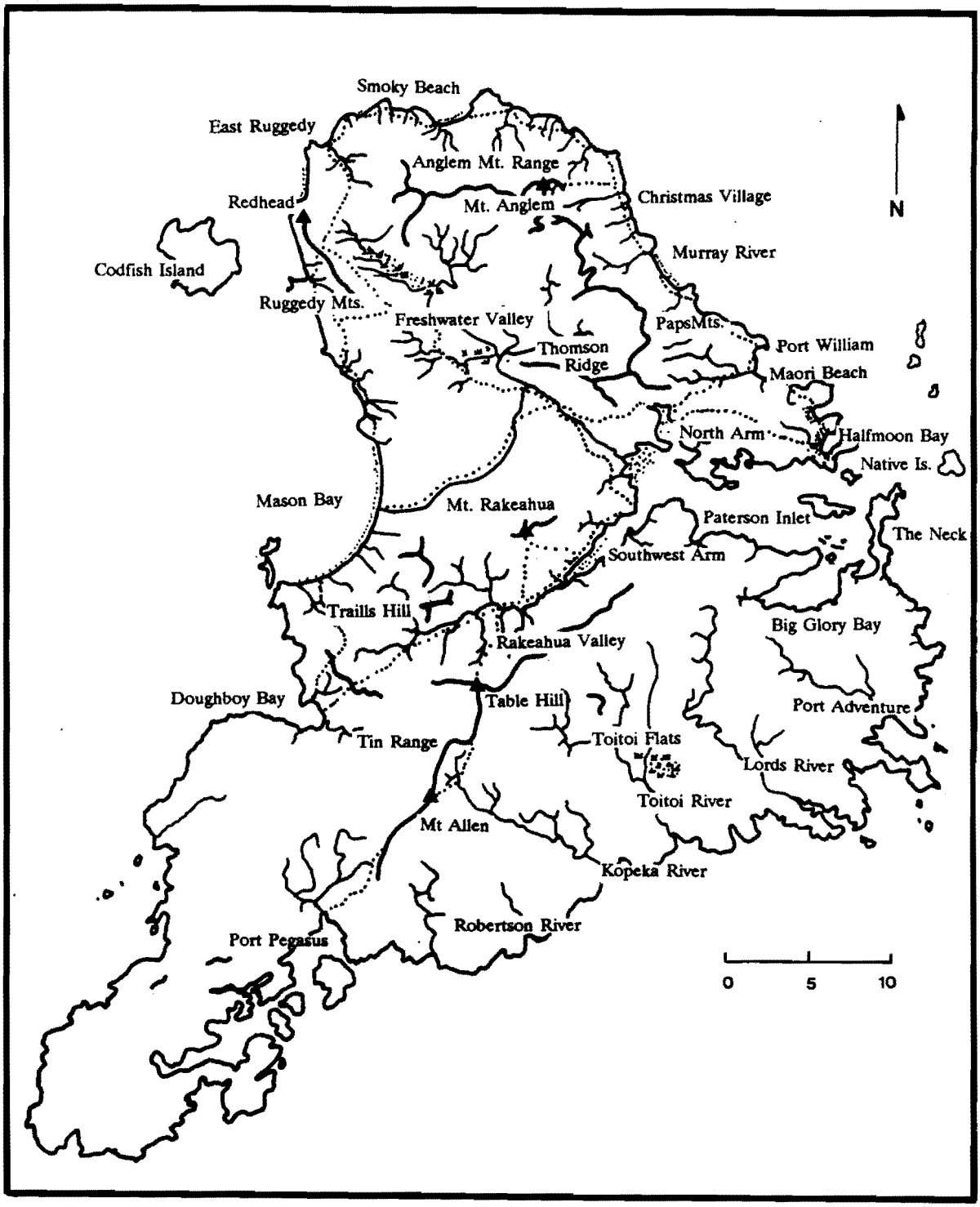


Fig. 2.1. Stewart Island place names mentioned in the text.

island was covered in forest only a small portion of the timber was millable, and only a limited amount of this was accessible. Nevertheless, an area east of a line joining North Arm and Port William (Fig. 2.1) was almost completely cut over. The only other milling was from small concessions granted at Murray River, the head of Big Glory Bay and the south shore of Paterson Inlet.

Attempts were made to extract gold from quartz at Redhead and some prospecting was carried out at Port Pegasus and Smoky Beach around 1866. Claims were also laid at Port William where shafts were sunk and sluicing races constructed. Payable quantities of gold were never found, but prospecting led to the discovery of tin in the Port Pegasus and Robertson River areas. Although about 100 claims were subsequently taken out, only about five are thought to have been actively worked (Piper 1961). Like gold, payable quantities of tin were never found, and by 1912 all ventures were wound up. Most evidence of activity in this era is now hidden by regenerating manuka and pine.

Attempts at farming Stewart Island were limited by infertile wet soils and the less than ideal climate (Wilson 1987). Major changes were wrought by burnoffs and attempts at drainage, but subsequent regeneration of vegetation has covered these over. The last major sheep run, the Island Hill Run at Mason Bay was closed when the lease expired in the mid 1980s, and already, pastures have been largely replaced by a vigorous regrowth of red tussock (*Chionochloa rubra*). Today there are only small runs on coastal properties around Halfmoon Bay.

From the 1830s onward, European settlements have been concentrated around Halfmoon Bay (Wilson 1987). The Island was sold to the New Zealand Government by the local Maori population in 1864 (Howard 1940) and by 1907 much of it was already reserved for the protection of scenery and natural history. Since 1931 the Stewart Island economy has been based mainly on fishing and to a lesser extent on tourism. Neither of these has had much impact on the island's flora and fauna.

TOPOGRAPHY

North of Mt. Rakeahua, the Island is dominated by the coastal Ruggedy, Paps, Thomson and Anglem mountain ranges which include the island's highest point, Mt. Anglem (980m a.s.l., Plate 2.1A). To the east of the Ruggedy Mountains, and west of the other three ranges, lie the wide, flat, expanses of the Freshwater Valley. This extends south to Patersons Inlet and Mt. Rakeahua, and west into the swampy flats and sand

dune complexes of Mason Bay (Plate 2.1B).

Between this northern area and a more extensive block of similar relief to the south, is the Rakeahua Valley (Plate 2.2) and the isolated, dome-like peak of Mt. Rakeahua (681m a.s.l., Plate 2.1B), which overlooks the southwest arm of Patersons Inlet.

The southern part of the island is dominated by the central Tin Range, which extends from Table Hill (716m a.s.l.) on the southern side of the Rakeahua Valley, to the southern shores of Port Pegasus. This mountain range is characteristically capped by granite domes that are most spectacular towards its southern end (Plate 2.1C). The highest point is Mt Allen (750m a.s.l.). On either side of the Tin Range are complex series of trellised river valleys and rolling hill country broken only by occasional swampy flats. The most extensive of these is Toitoi flats on the eastern side of the island.

The east coast of Stewart Island is composed of a relatively sheltered complex of drowned river valley systems, with long inlets, tidal flats, beaches and rocky headlands. To the west, the coastline is much steeper, higher, and less indented apart from a few prominent beaches, the most notable being the 12 km long Mason Bay (Wilson 1987).

Most rivers on Stewart Island are unnamed. Therefore, most of the names I use in the text of this thesis are unofficial ones usually based on a prominent local feature that is named on Lands and Survey maps.

SOILS

The soil pattern of Stewart Island is generally characterised by altitudinal and latitudinal sequences of soils formed on a dioritic or granitic base. These sequences are modified by soils formed on substantial accumulations of wind blown sand, mainly in western locations, gley and recent soils on alluvium in broad inland valleys, and organic soils or basin peat deposits (Leamy 1974). The altitudinal and latitudinal sequences produce arrays of soils ranging from southern podzolised yellow-brown earths, through intergrades between these and organic soils, to organic soils (Leamy 1974).

Blanket peat is extensive in the south, but very local in the north (Wilson 1987). There are substantial areas of basin peat (Kini soils), e.g., Toitoi Flats, Rakeahua Valley, and Deceit Peaks, but raised peat bogs (Otanomomo soils) appear to be restricted to small areas between the

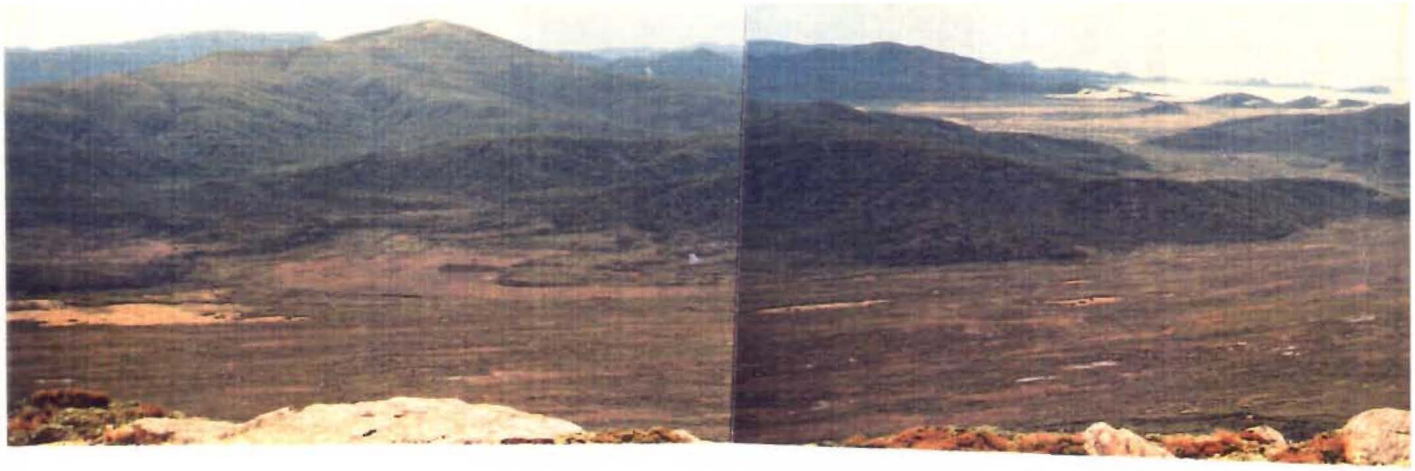
Plate 2.1A. Northern Stewart Island, looking across the Freshwater Valley from Mt. Rakeahua towards the Anglem / Paps mountain ranges (on the right) and Ruggedy Mountains (middle left). Photo A. M^{c}Intosh.

Plate 2.1B. The Freshwater Flats extend south to the dome like peak of Mt. Rakeahua and west into Mason Bay (Mason Bay dunes on the Right). Photo A. M^{c}Intosh.

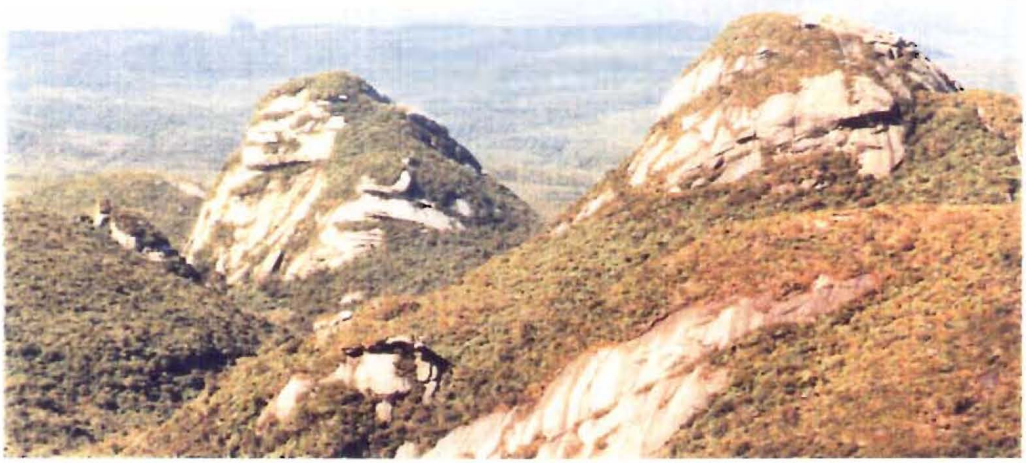
Plate 2.1C. Granite domes near the southern end of the Tin Range.

A

B



C



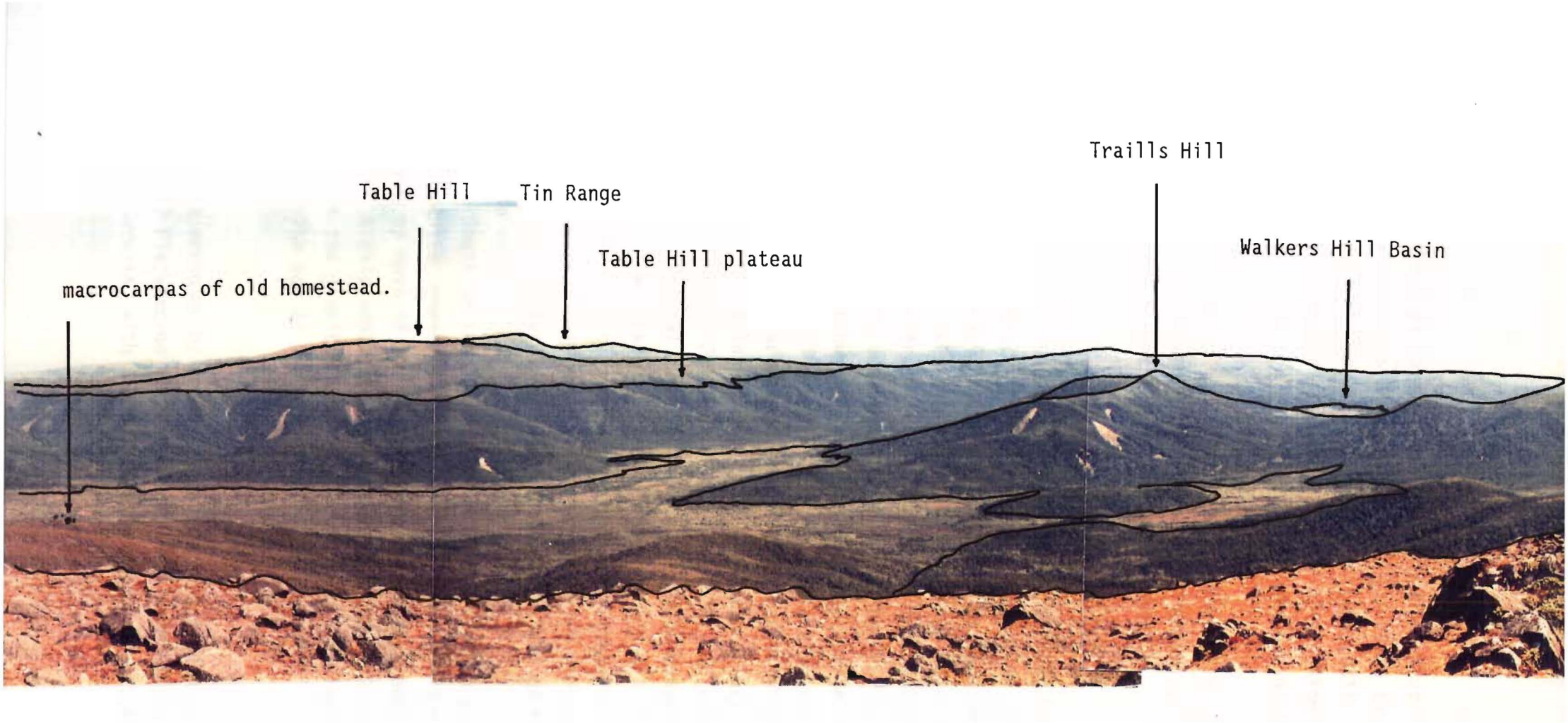


Plate 2.2. Looking south over the Rakeahua River valley (in the foreground) towards Table Hill and the central Tin Range. Photo A McIntosh.

northeast of Mason Bay plains and the Freshwater River (Wilson 1987).

Stewart Island soils are variously well drained to poorly drained, acidic and mostly of very low fertility (Wilson 1987). They are probably low in calcium, phosphorus, and potassium, a condition confirmed on North Island (northeast coast of Stewart Island) where Kennedy (1978) found low pH, and low availability of these elements.

Vegetation patterns on some alluval soils suggest that they are moderately fertile, whereas the fertility of some headlands is enhanced by large numbers of nesting petrels and penguins.

GEOLOGY

An account of the geology of the region is given by Watters *et al.* (1968), and more detailed but unpublished studies of local areas (e.g. Waddell 1971, Cook 1984, Allibone 1986, Frevin 1987, Peden 1988) have been carried out by research students from Otago University.

According to Watters *et al.* (1968) three distinct geological areas exist. Wilson (1987) summarised their main features as follows: "(i) North of Ruggedy-Freshwater-Paterson Inlet depression, Permian to Carboniferous ultrabasic, basic and intermediate intrusives, mainly diorite and tonalite are associated with volcanics of the south-western margin of the New Zealand geosyncline (Anglem complex);

(ii) The Ruggedy-Freshwater-Paterson Inlet lowlands probably represent an erosional feature along a fault-depressed zone; Permian to Carboniferous low- grade quartzo-feldspathic and chlorite schist (Paterson group) are closely associated with intensely crushed granite. This is all extensively overlain by terrace of Pleistocene age, by recent stream alluvium, estuarine and swamp deposits, and by wind- and water-borne sand.

(iii) South of the depression is mainly Permian course-grained biotite granite, gneissic in some places, known as Rakeahua Granite. This makes up most of the southern two-thirds of Stewart Island. On the Tin Range, highly schistose metasediments (Pegasus Group) form roof pendants in the granite, with tin and tungsten-bearing veins along the contacts. The age of the parent rock is unknown".

GLACIATION

Cirques occupied by small lakes and associated moraines are clear evidence of Pleistocene glaciation near the summit of Mt. Anglem (Wilson 1987). Otherwise, with the possible exception of Mt. Allen where a small

lake basin on its eastern flanks may also be of glacial origin (Watters *et al.* 1968), the island appears to have escaped the direct influence of moving ice (Wilson 1987).

During the Pleistocene glaciation, Stewart Island was connected to the southern mainland, and at this time it appears that forest was completely eliminated by the cold temperatures (Fleming 1963). Silver Beech (*Nothofagus menziesii*) is the most cold tolerant of New Zealand's moist forest tree dominants, and would presumably be the last species to have been eliminated as temeratures declined (Wells and Mark 1966). Since there is apparently no reason to suppose that Silver Beech was never present on Stewart Island (Wells and Mark 1966), its absence today suggests that deforestation was complete at some time in the past.

PRESENT VEGETATION

The vegetative cover of Stewart Island is largely intact although it has been modified to some extent (Wilson 1987).

Fire, milling and farming have affected only small areas and regeneration has generally been vigorous. The effects of introduced mammals have been greater and more widespread. The Australian brushtail oppossum (*Trichosurus vulpecula*), red deer (*Cervus elaphus*), whitetail deer (*Odocoileus virginianus*), kiore (*Rattus exulans*), Norway rat (*Rattus norwegicus*), ship rat (*Rattus rattus)* and feral sheep (*Ovis aries*) are all present on Stewart Island. Some plant species once abundant and widespread, have largely been eliminated as conspicuous elements of the vegetation across most of the region. Notable amoungst these are the seral species, *Fuchsia excorticata*, *Aristotelia serrata* and *Schefflera digitata*, and also *Coprosma lucida*, and *Asplenium bulbiferum*. Others such as *Dicksonia squarrosa* (tree fern), *Griselinia littoralis* (broadleaf), and *Pseudopanax colensoi* var. *fiordensis* have declined considerably, but are still common (Wilson 1987). Although Wilson (1987) contends that natural patterns of vegetation are intact, he would probably agree with Veblen and Stewart (1980) and Nugent and Challies (1988) that unless deer and oppossum numbers are reduced, major changes to the structure and composition of understory species, tree ferns and subcanopy trees will be brought about in the future as adult trees gradually die out and are not replaced.

The first comprehensive description of the vegetation of Stewart Island was made by Cockayne (1909). Since then, substantial

contributions to the knowledge of the Stewart Island vegetation have been made by several workers. A good summary of these is given by Wilson (1987) who has also provided the most recent and comprehensive description of the flora. What follows is principally based on his text.

Wilson (1987) divided the Stewart Island plant community into nine groups and 27 subgroups. I shall briefly outline the most widespread.

The rimu (*Dacrydium cupressinum*)/ kamahi (*Weinmannia racemosa*) association is the most extensive community type, and its variants cover approximately 60 percent (1000 km^2) of the land area. This association extends from sea level to about 300 m and is commonest on rolling hill country. It is characterised by relatively small, and generally widely spaced rimu trees that emerge over a canopy of kamahi and to a lesser extent other hardwoods, notably southern rata (*Metrosideros umbellata*). Large rata may be semi-emergent above the kamahi, whereas miro (*Prumnopitys ferruginea*) and Hall's totara (*Podocarpus hallii*) are soft wood emergents commonly associated with rimu, but never over topping it.

Understory vegetation and ground cover is dominated by hardwoods including stinkwood (*Coprosma foetidissima*), broadleaf, and *Pseudopanax simplex*, climbers, of which *Rubus australis* and *R. cissoides* are most widespread, and also supplejack (*Ripogonum scandens*) and climbing rata (*Metrosideros diffusa*). The tree ferns *Dicksonia squarrosa* and *Cyathea smithii* are also prominent, as are the ferns *Blechnum discolor* and *B. procerum* and juvenile canopy trees. Understory diversity is greatest in cool, deeply shaded, fern gullies, especially where deer are uncommon. Epiphytic ferns, bryophytes and lichens are abundant throughout.

Above 300 m, the rimu/kamahi association gives way to dense dwarf forest and scrub. Dwarf forests (Wilson's inland low forest and scrub) consist of short, 1-8 m tall trees, and are characterised by at least two, more-or-less prominent, canopy forming species from the following list: inaka (*Dracophyllum longifolium*), leatherwood (*Olearia colensoi* var. *argentea*), rata, manuka (*Leptospermum scoparium*), pink pine (*Halocarpus biformis*), yellow silver pine (*Lepidothamnus intermedius*) and kamahi. These canopy trees occur in nearly every possible combination, and in some places five or six species may be prominent in roughly equal proportions. Elsewhere, a single species of *Olearia* or pine, tends to predominate. Dwarf forest occupies extensive areas from about 300 to 650

m, above the altitude attained by rimu. At even higher altitudes, it becomes increasingly restricted to steeper sites, and is replaced on more gentle slopes by alpine herbmoor, tussock lands, and cushion fields. Smaller tracts of dwarf forest occur below 300 m a.s.l. where a variety of conditions (drainage, fertility) combine to inhibit the development of taller, mixed podocarp forest. In the south, extensive tracts reach nearly to sea level. In all, Wilson (1987) estimates some 350 km^2 of Stewart Island are occupied by dwarf forest and scrub.

The next most extensive vegetation type is coastal low forest and scrub, which occurs in most parts of the island between tall forest and the sea. Its composition is determined largely by the degree of wind exposure and also by the tolerances of various species to wind blown salt. Hence, it penetrates further inland on exposed western and southern coasts. Muttonbird scrub (*Brachyglottis rotundifolia*) is usually dominant, but it may be mixed with various forest species, especially *Myrsine* spp., rata and *Dicksonia*. However, two *Olearia* species, *O. lyalli*, and *O. oporina*, are often dominant on highly organic soils, or on more exposed coasts, respectively. Other important components of coastal scrub are; *D. longifolium*, *Hebe elliptica*, and broadleaf. Characteristic understorey species include *Asplenium obtusatum*, *Phormium cookianum*, *Blechnum durum*, and sometimes the sedges *Carex appressa*, and *Uncinia uncinata*. Under many canopies the floor is almost completely bare. Often this is because canopies are extremely dense but it can also reflect the activities of penguins and petrels.

The last major vegetative type is dominated by manuka and was divided by Wilson (1987) into two groups, manuka canopy low forest/scrub, and open *Leptospermum/Empodisma* scrubland.

Much of the manuka-dominated low forest and scrub is a successional type that will be succeeded by a rimu/kamahi association. These seral communities have established on ground bared by fire, landslides, clearfelling, windthrow, and sometimes by floods. Extensive areas of quasi-climax and climax communities with manuka dominated canopies also exist, particularly on poorly drained, infertile soils in wind exposed conditions, and where continuing conditions of flooding and water logging inhibit replacement of *Leptospermum* by other canopy trees. The most frequent associates are *Blechnum procerum*, *Dracophyllum longifolium*, *Cyathodes juniperina*, *Gahnia procera*, and *Halocarpus biformis*. In all,

some 50-60 km^2 of Stewart Island are estimated to be covered by a more or less pure canopy of manuka.

Open *Leptospermum/Empodisma* shrubland also occcupies 50-60 km^2 of Stewart Island, principally on open ground at about sea level, on the Ruggedy /Freshwater flats, lower Rakeahua flats, low lying grounds near Port Pegasus, and ancient dunes inland from Mason Bay. Described by Cockayne (1909) as 'heath', this association is generally persistent only on wet, organic soils. Floristically, the communities are well marked; manuka is commonly 1-3 m tall, and well spaced, *D. longifolium* is invariably present, and *C. juniperina* is very common. Between these shrubs, the ground is usually covered with *Empodisma minus* and *Lycopodium ramulosum*. *Gleichenia dicarpa* may also be common. Much of this shrubland has been burnt during the last 100 years, although regeneration now appears to be complete. However, destruction of manuka low forest/scrub principally by fire, has allowed the heath like scrubland to expand on to a wider range of soils, in a manner similar to the expansion of pakahi on the west coast of the South Island. Often heath will grade into manuka low forest, which in turn grades into mixed podocarp forest. Tussockland, sedgeland, grassland, herbfields, fernland, scrubland and wetlands cover as much as 20 percent of the surface area of Stewart Island. Most are seral communities associated with past disturbances such as fire, although some occur in specialised environments characterised by such features as high winds, poor drainage, or sandy soils.

Both seral and equilibrium vegetation on Stewart Island is overwhelmingly indigenous; associations involving naturalised species are very local in occurrence (Wilson 1987).

PRESENT CLIMATE

The region is marked by a cool temperate, highly oceanic, humid, windy climate lacking extremes of temperature or seasonal change. Monthly mean temperatures from 1951 to 1980 ranged from 5.5-13.0 (Anon. 1981).

Exposed coasts and ridges are subject to very strong winds, and fogs may persist for days on the more sheltered east coast and mountain summits. The weather is frequently cloudy and precipitation is distributed evenly throughout the year. Mean annual rainfall for Halfmoon Bay (1914-1975) was 1467 mm, with an average of 195 raindays (Anon. 1980). Annual rainfall is slightly lower than this along the north east coast (estimated mean = 1250 mm) and may be up to 3750 mm in

the high country (Leamy 1974). Rainless periods of up to two to three weeks are rare. Snow occurs infrequently, and on average there are 63.4 ground frosts per annum (Anon. 1980).

SPECIFIC STUDY AREAS

Much of my field work was based in the Rakeahua and Maori River Valleys. Specifically, fish distribution and diet studies (see Chapter 6 & 7), and the leaf pack colonisation experiment (see Chapter 5) were carried out in one or both of these valleys.

The Rakeahua River Valley (Plate 2.2)

The Rakeahua River is a large, 6^{th} order stream (width of lower reaches 10-20 m, depth 2-3 m), that flows east into the southwest arm of Paterson Inlet (Fig. 2.2). From its source in rolling hill country that backs on to Mason and Doughboy Bays, to its tidal lower reaches, it is approximately 14 km long with a catchment area of about 106 km^2.

Its main branches have gentle gradients (Walkers Hill gorge rises 40 m in 2 km) , with short gorges and a meandering course in the lower hill country, and on the alluvial flats of the Rakeahua flood plain. In contrast, many of the smaller tributaries that flow off Table Hill plateau and Trails Hill tend to be short and fast flowing, with a series of waterfalls and steep gorges in their middle and upper reaches.

The hills to the south rise sharply on to the Table Hill plateau, whereas the hills to the west and north are more gentle; stream gradients reflect this topography. Vegetation in the Rakeahua Valley is dominated by mixed podocarp forest (rimu, totara, miro, rata, and kamahi canopy) which grades into manuka stands, dwarf forests, subalpine scrub, and finally herbfields, moors, tundras, and bog communities at altitudes above 250-300 m (Meurk and Wilson 1989). Riparian vegetation, particularly on the Rakeahua Flats and in Walkers Hill basin, is a rich mosaic of mature riverine forest dominated by kahikatea and the other podocarp canopy trees, mixed manuka / hardwood forest, manuka forest and thicket, grass, red tussock scrubland, sedge-fern basin mire and sphagnum swamp. Much of this mosaic is a consequence of the variable drainage patterns and soil types within the valley, and partly the result of burnoffs associated with past farming practices.

Sheep and cattle were first run in the Rakeahua Valley in 1888, on what was known as Run 425, an area of about 900 acres on the north bank of the river about a mile from the mouth (Howard 1940). The area proved

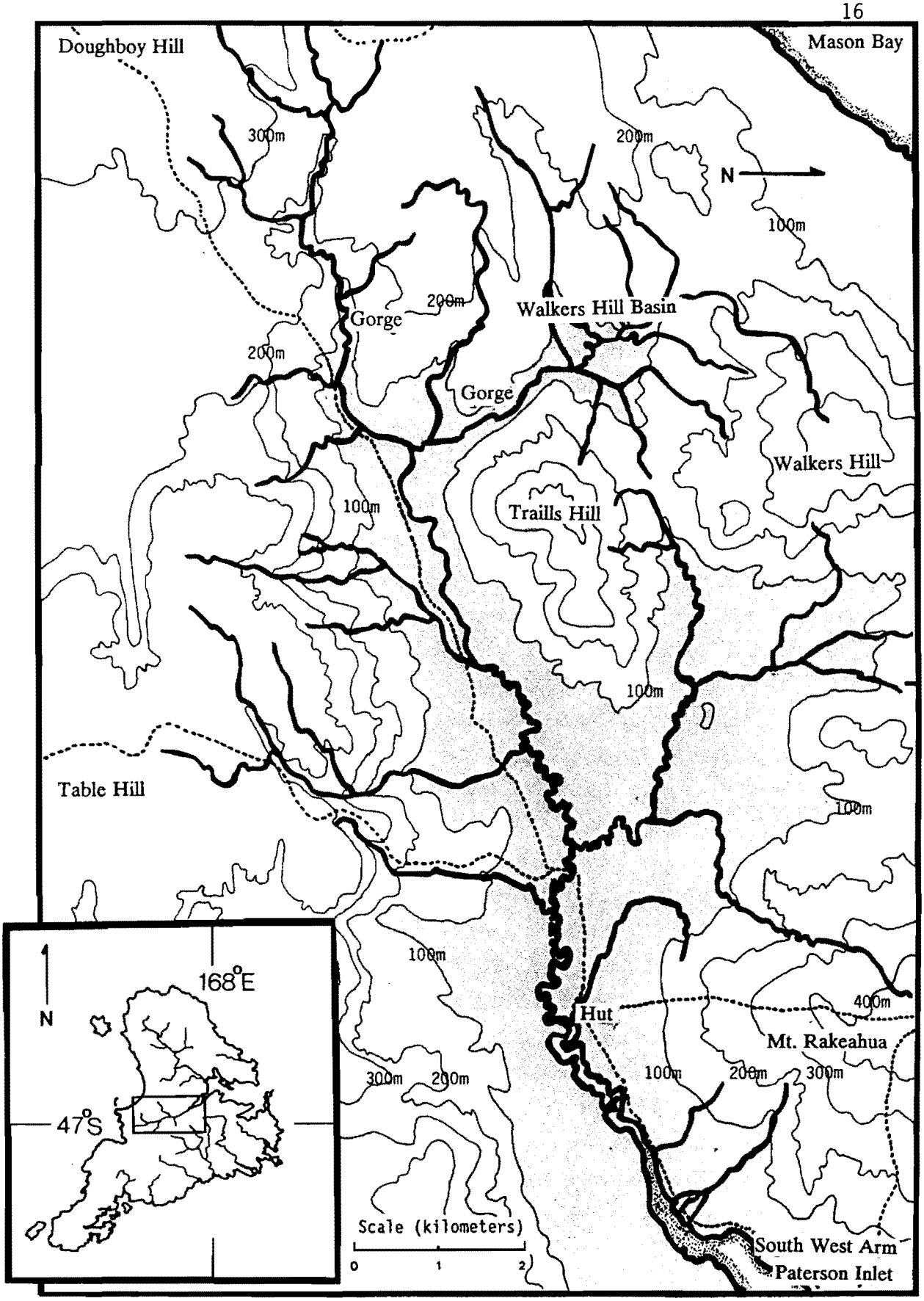


Fig. 2.2. The Rakeahua River Valley.

to be too wet for sheep, although there is some suggestion (Meurk and Wilson 1989) that cattle were run there until the early 1940s, even though much of the valley became a scenic reserve in 1905. All that remains of the run today are a few old fences, some macrocarpas (*Cupressus macrocarpa*) associated with the knoll where the Department of Conservation hut stands today, and a few clearings of old pasture grasses that are gradually giving way to encroaching native vegetation (Meurk and Wilson 1989). Vigorous regrowth of manuka, red tussock, native grasses and ferns has rapidly covered most clearings.

In the main valley, deep deposits of alluvium intergrade with yellow-brown sands and podzolised yellow brown earths on the valley sides. In poorly drained parts of the valley that are never flooded with alluvium, soils intergrade between acidic blanket and basin peats.

The climate is cloudier and wetter than in Halfmoon Bay. Thus average annual rainfall at the Rakeahua hut between 1971 and 1981 was 2126 mm (Wilson 1987) and at higher altitudes it probably reaches 3000 mm (Meurk and Wilson 1989).

Access to the valley is either by small boat/dinghy from Halfmoon Bay, or via the southwest tramping circuit. Tramping tracks follow the main branch of the river on to Doughboy Hill, and other tracks go to the summits of Mt. Rakeahua and Table Hill (Fig. 2.2).

The Maori River Valley

The "Maori River" is the large stream flowing into the estuary at the northern end of Maoribeach, Port William Bay (Fig. 2.3). With a catchment area of about 20 km^2 and a length of about 8 km it is a much smaller river than the Rakeahua. It flows through low lying hill country (Fig. 2.3) covered in regenerating podocarp forest. The vegetative cover of the catchment has been greatly modified by milling operations between 1913 and 1931. Very few large podocarps remain, but vigorous regeneration has occurred and a continuous cover of hardwood species is already well established (Meurk and Wilson 1989). The forest cover is consequently a combination of second growth kamahi short forest and cutover rimu/kamahi forest. Subcanopy species include *Dicksonia squarrosa*, *Coprosma* sp., *Pseudopanax simplex*, *Carpodetus serratus*, *Pseudopanax crassifolium* (lancewood), *Griselinia littoralis* (broadleaf), *Pittosporum tenuifolium* (Kohuhu), *Myrisine* sp. and juvenile canopy trees. Tangles of supplejack (*Ripogonum scandens*), lawyer (*Rubus* spp.) and climbing rata (*Metrosideros diffusa*) occur in places, whereas crown fern

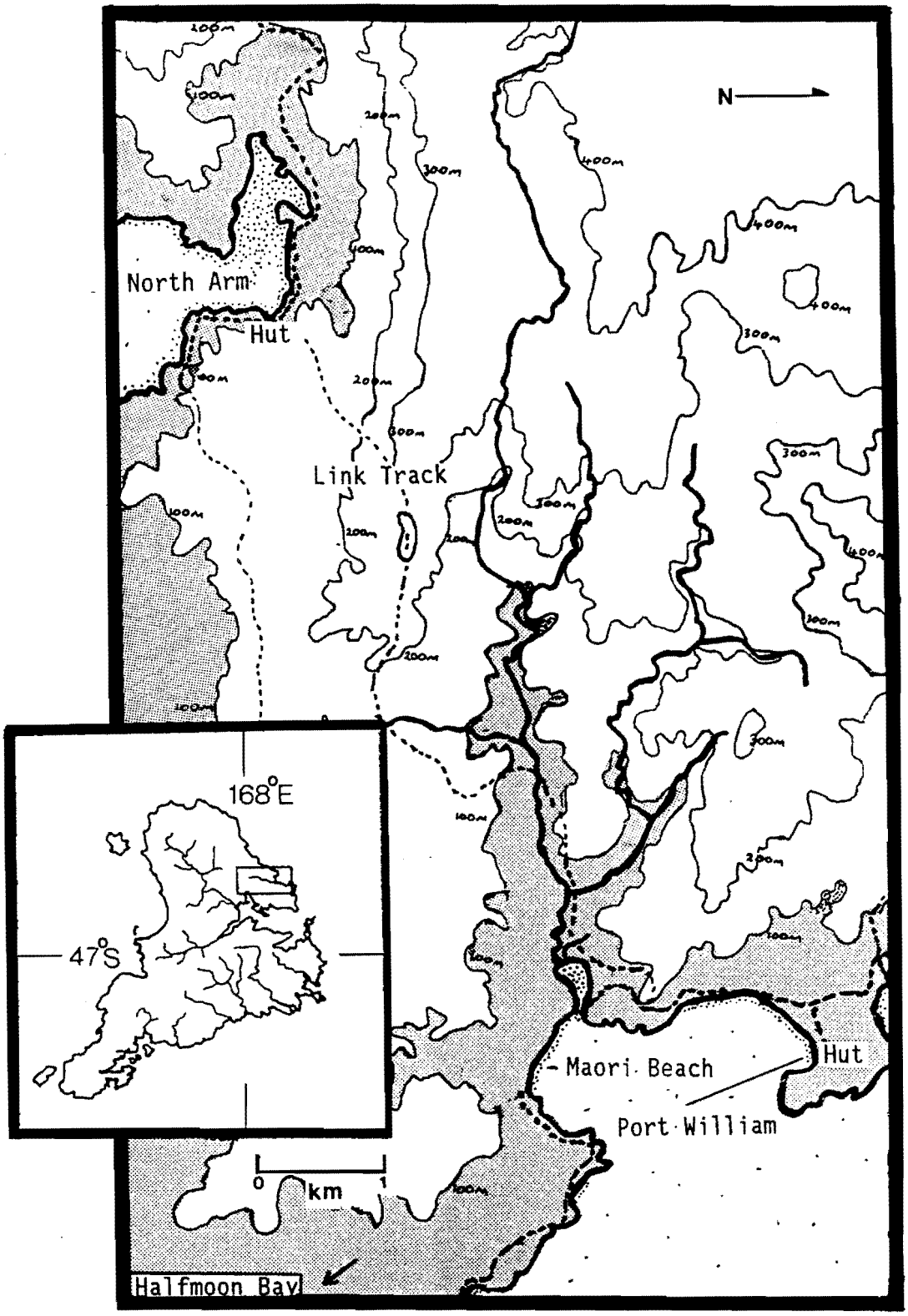


Fig. 2.3. The Maori River Valley.

(*Blechnum discolor*), *Nertera* sp. and hooked sedge are common on the ground (Meurk and Wilson 1989).

The area is underlain by diorite, and soils include podzolised yellow brown earths, well drained alluvium and yellow brown sands (Meurk and Wilson 1989).

Climate is very similar to that recorded at Halfmoon Bay which is only about 6 km to the south. Consequently, it rains frequently and the mean annual rainfall is about 1500 mm.

Access to the valley is by the northwest tramping circuit from Lee Bay and Halfmoon Bay (Fig.2.3). A new track linking Port William and North Arm runs the length of the valley, crisscrossing the river in its lower reaches. A boat can also be taken to Port William and small dinghies can land on Maoribeach in fine weather.

CHAPTER 3

CHARACTERISTICS OF STEWART ISLAND STREAMS

INTRODUCTION

On Stewart Island, moderate to high rainfall, diverse relief, variable soils and oceanic influences give rise to a variety of stream types. They range from short, boulder strewn streams flowing down the steep coastal mountains, to large, meandering, sandy bottomed rivers with sources in the rolling hill country of the island's interior.

During the course of this study, I measured several physicochemical and morphological characteristics of a large number of streams, and report the results of this work below.

METHODS

Physicochemical data were collected from 78 1st to 6th order streams on Stewart Island (Fig. 3.1). Sites were sampled between August 1987 and November 1989, although most (65) were visited in January 1989.

Water samples were collected in 530 ml polyethylene containers, and stored initially in cool dark places in the 'bush' as the isolation of sites made it impractical/impossible to freeze samples. It was up to three months before some samples could be analysed.

Effects of storage on chemical parameters

To determine whether long periods of storage between sampling and analysis affect water chemistry, periodic measurements were taken of stored samples over a three month period. Ten, 530 ml water samples were taken from two contrasting sites close to Halfmoon Bay and frozen within 24 hours. On return to the University of Canterbury all samples were thawed and stored at room temperature, out of direct sunlight. Chemical parameters (pH, conductivity, absorbance at 360 nm, and alkalinity) were measured at weekly intervals for six weeks, and after almost 12 weeks. Samples for analysis were taken from a new container every second week, so that no more than two readings were taken from a single water sample.

Measurement of physicochemical factors

Hydrogen ion concentration (pH) was measured with a hand held Advantec pocket pH meter. The meter had been calibrated against a

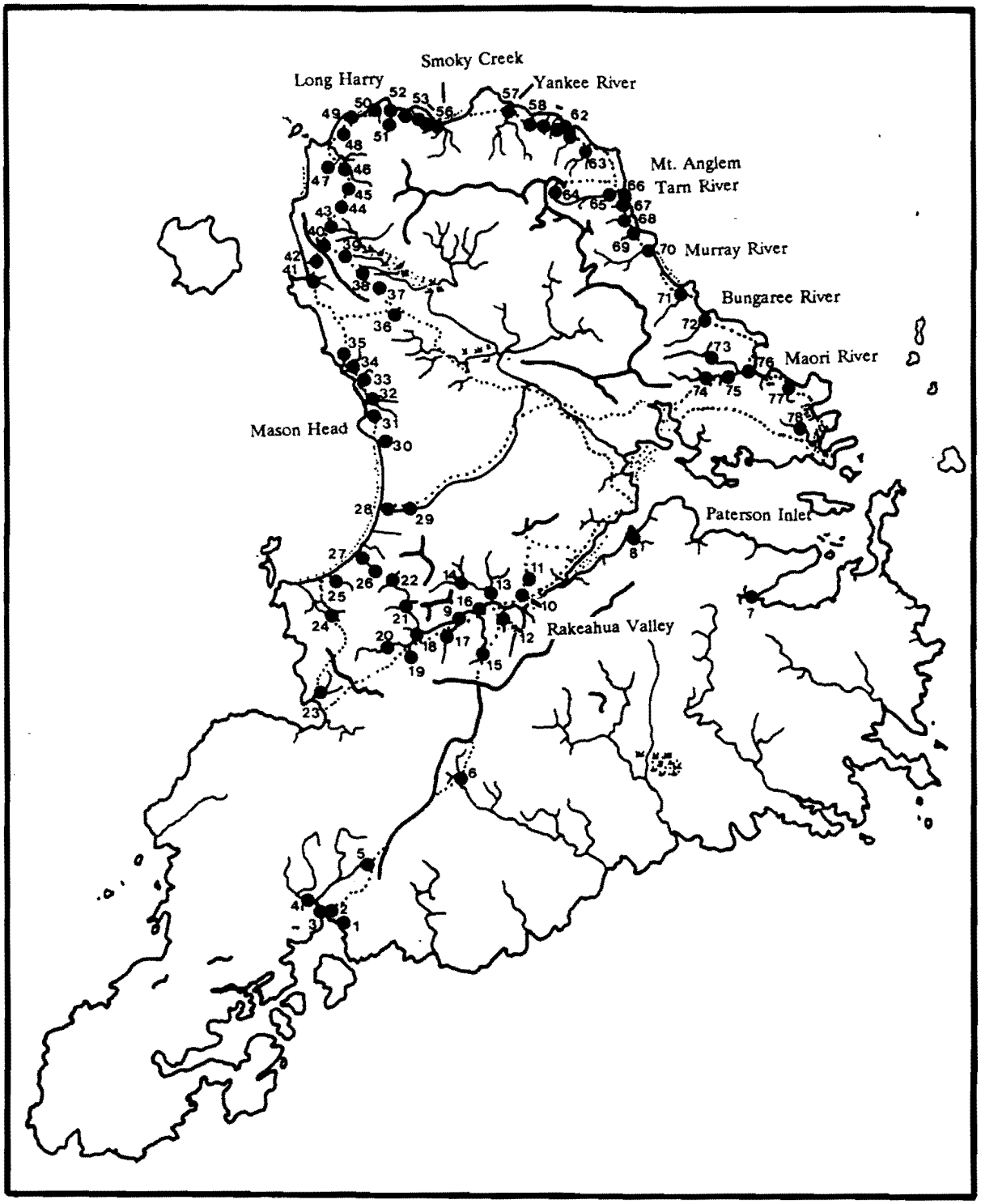


Fig. 3.1. Physicochemical survey sites, August 1987 and November 1989.

Metrohm 632 pH meter by M.J. Winterbourn and found to be accurate to 0.1 of a pH unit over the pH range 4.5 to 7.5. The Advantec meter responded rapidly (Unlike the Metrohn 632) and showed little inclination to drift.

Conductivity was measured with a Radiometer CD2e meter and is expressed as mS m^{-1} at 25^0C (Golterman and Clymo 1969).

Alkalinity was determined using the pH 4.5 titration method on 100 ml water samples (Mackereth 1963).

Dissolved organic carbon (DOC) concentration was estimated spectrophotometrically. Absorbance at 360 nm was measured in a 1 cm cell on a Kontron-Uvikon spectrophotometer and converted to DOC concentration (g m^{-3}) using a predetermined relationship. This relationship was established by measuring DOC concentrations of 22 water samples covering the range of absorbance values expected. Filtered (glass fibre filters, nominal pore size 1 μm), 100 ml water samples were evaporated to dryness and DOC concentration was determined using the microdichromate oxidation procedure (Maciolek 1962) as modified by Collier (1987).

Mercuric sulphate was added to each sample to precipitate out any chloride ions present, and so prevent their oxidation by chromic acid.

DOC concentration was calculated with the equation;

$$DOC\ (g\ m^{-3}) = (A - B) \times N \times 3.36 \quad \text{(Collier 1987)}$$

where A = ml of ferrous sulphate used to titrate a reagent blank
B = ml of ferrous sulphate used to titrate sample
N = normality of ferrous sulphate

Absorbance at 360 nm was related linearly to DOC concentration (r^2 = 0.89) and the latter could therefore be estimated with the equation;

$$DOC\ (g\ m^{-3}) = 50.18 \times (\text{Absorbance}) + 4.18$$

Chlorinity was measured by titration of 100 ml samples with silver nitrate (0.1N) using a potassium chromate (K_2CrO_4) indicator (Cox 1967).

Sodium ion concentration were measured on an E.E.L. flame photometer (Mark 2) with a sodium filter.

Measurements of other stream characteristics

Stream channel stability was evaluated using the method of Pfankuch (1975) (Fig. 3.2). The Pfankuch survey is a systematic procedure in which a series of physical factors are examined in a stream reach and given numerical scores. Upon summing the scores for individual factors, an overall rating is obtained and this can be translated into one of four subcategories: excellent, good, fair or poor. The stream ratings

Item Rated	Stability Indicators by Classes							
UPPER BANKS	**EXCELLENT**		**GOOD**		**FAIR**		**POOR**	
1 Landform slope	Bank slope gradient <30%	(2)	Bank slope gradient 30-40%	(4)	Bank slope gradient 40-60%	(6)	Bank slope gradient 60%+	(5)
2 Mass-wasting (existing or potential)	No evidence of past or any potential for future mass-wasting into channel.	(3)	Infrequent and/or very small. Mostly healed over. Low future potential.	(6)	Moderate frequency and size, with some raw spots eroded by water during high flows.	(9)	Frequent or large, causing sediment nearly year-long OR imminent danger of same.	(12)
3 Debris jam potential (floatable objects)	Essentially absent from immediate channel area.	(2)	Present but mostly small twigs and limbs.	(4)	Present, volume and size are both increasing.	(6)	Moderate to heavy amounts, predominantly larger sizes.	(8)
4 Vegetative bank protection	90%+ plant density. Vigor and variety suggests a deep, dense, soil binding root mass.	(3)	70-90% density. Fewer plant species or lower vigor suggests a less dense or deep root mass.	(6)	50-70% density. Lower vigor and still fewer species form a somewhat shallow and discontinuous root mass.	(9)	<50% density plus fewer species and less vigor indicate poor, discontinuous and shallow root mass.	(12)
5 Channel capacity	Ample for present plus some increases. Peak flows contained. W/D ratio <7.	(1)	Adequate. Overbank flows rare. Width to Depth (W/D) ratio 8 to 15.	(2)	Barely contains present peaks. Occasional overbank floods. W/D ratio 15 to 25.	(3)	Inadequate. Overbank flows common. W/D ratio >25.	(4)
LOWER BANKS								
6 Bank rock content	65%+ with large, angular boulders 12"+ numerous.	(2)	40 to 65%, mostly small boulders to cobbles 6-12".	(4)	20 to 40%, with most in the 3-6" diameter class.	(6)	<20% rock fragments of gravel sizes, 1-3" or less.	(8)
7 Obstructions Flow deflectors Sediment traps	Rocks and old logs firmly embedded. Flow pattern without cutting or deposition. Pools and riffles stable.	(2)	Some present, causing erosive cross currents and minor pool filling. Obstructions and deflectors newer and less firm.	(4)	Moderately frequent, moderately unstable obstructions and deflectors move with high water causing bank cutting and filling of pools.	(6)	Frequent obstructions and deflectors cause bank erosion year-long. Sediment traps full, channel migration occurring.	(8)
8 Cutting	Little or none evident. Infrequent raw banks less than 6" high generally.	(4)	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	(6)	Significant. Cuts 12-24" high. Root mat overhangs and sloughing evident.	(12)	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	(16)
9 Deposition	Little or no enlargement of channel or point bars.	(4)	Some new increase in bar formation, mostly from coarse gravels.	(8)	Moderate deposition of new gravel and coarse sand on old and some new bars.	(12)	Extensive deposits of predominantly fine particles. Accelerated bar development.	(16)
BOTTOM								
10 Rock angularity	Sharp edges and corners, plane surfaces roughened.	(1)	Rounded corners and edges, surfaces smooth and flat.	(2)	Corners and edges well rounded in two dimensions.	(3)	Well rounded in all dimensions, surfaces smooth.	(4)
11 Brightness	Surfaces dull, darkened or stained. Gen. not "bright".	(1)	Mostly dull, but may have up to 35% bright surfaces.	(2)	Mixture, 50-50% dull and bright, ±15%, i.e. 35-65%.	(3)	Predominantly bright, 65%+, exposed or scoured surfaces.	(4)
12 Consolidation or particle packing	Assorted sizes tightly packed and/or overlapping.	(2)	Moderately packed with some overlapping.	(4)	Mostly a loose assortment with no apparent overlap.	(6)	No packing evident. Loose assortment, easily moved.	(8)
13 Bottom size distribution and percent stable materials	No change in sizes evident. Stable materials 80-100%.	(4)	Distribution shift slight. Stable materials 50-80%.	(8)	Moderate change in sizes. Stable materials 20-50%.	(12)	Marked distribution change. Stable materials 0-20%.	(16)
14 Scouring and deposition	Less than 5% of the bottom affected by scouring and deposition.	(6)	5-30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	(12)	30-50% affected. Deposits and scour at obstructions, constrictions, and bends. Some filling of pools.	(18)	More than 50% of the bottom in a state of flux or change nearly year-long.	(24)
15 Clinging aquatic vegetation (moss and algae)	Abundant. Growth largely moss-like, dark green, perennial. In swift water too.	(1)	Common. Algal forms in low velocity and pool areas. Moss here too and swifter waters.	(2)	Present but spotty, mostly in backwater areas. Seasonal blooms make rocks slick.	(3)	Perennial types scarce or absent. Yellow-green, short term bloom may be present.	(4)
	COLUMN TOTALS							

Add the values in each column for a total reach score here (E___ + G___ + F___ + P___ = ___).

Reach score of: <38 = Excellent, 39-76 = Good, 77-114 = Fair, 115+ = Poor.

Fig. 3.2. Pfankuch (1975) stream stability index forms.

represent a summary of the resistive capacity of stream channels to the detachment of bed and bank materials, and provides information about the capacity of streams to adjust and recover from potential changes in flow and/or increases in sediment production (Pfankuch 1975).

Observations on stream structure, size, depth, percentage moss cover, presence of algae, current velocity, wood volume, and degree of shading, were noted on general survey forms (Fig. 3.3) adapted from the New Zealand freshwater fish data base forms (McDowall & Richardson 1983).

Long term temperature records were obtained at four sites in the Rakeahua Valley on maximum/minimum thermometers read and reset on 4 occasions between April and December 1989. The four sites represented a cross section of stream types from 1st to 5th orders including two straight faster-flowing, shallow reaches, and two deeper, slower flowing meandering channels. Spot temperatures were taken routinely in other streams at the time of faunal sampling.

RESULTS AND DISCUSSION

Effects of storage on chemical parameters

A summary of the results of the validation experiment is given in Table 3.1. Although parameters measured changed a little over time, there was no apparent linear change. Some of the differences found can probably be attributed to temperature changes, inter-sample variation and errors of measurement. Given the relatively small magnitude of changes that occurred in water samples during storage, I am confident that the values obtained from the samples collected during my summer surveys, and by necessity stored for periods of up to 3 months, are reasonably accurate indications of true water chemistry conditions.

Physicochemical and morphological features

Physicochemical conditions of 78 sites on Stewart Island streams are summarised in Table 3.2. Dissolved organic carbon and pH of water samples ranged from 5.0 to 23.2 g m^{-3}, and 4.6 to 7.3, respectively. Just under 40 % of all sites were acidic (pH < 6.4) brownwaters with DOC concentrations greater than 10.0 g m^{-3} (Figs 3.5A & B). The strong negative correlation between pH and DOC concentration (r_s = -0.74, P <

INVERTEBRATE SURVEY FORM

Date Time Observer	River/Lake system						Catchment number	Average width (m)
Organisation Sampling method	Sampling locality Access						Altitude (m)	Average depth (m)
	Map No. NZMS1 NZMS260		Coords.				Inland distance (km) Permanent yes water no/unknown	Maximum depth (m) Tidal yes water no/unknown
			Photo No.					
HABITAT DATA								
Water	Colour blue/green/tea/uncolour/other				Clarity clear/milky/dirty.			Temp
Habitat (%) type	Still	Backwater	Pool	Run	Riffle	Rapid	Cascade	pH
Substrate type (%)	Mud	Sand	Fine gravel	Coarse gravel	Cobble	Boulder	Bedrock	Conductivity
Cover (%)	Substrate	Weed algae	Instream debris	Bank vegt.	Undercut banks	O/head shade	Other	DOC
Catchment vegetation (%)	Native forest	Exotic forest	Horticulture	Urban zone	Scrub	Pastoral	Other	
Riparian vegetation (%)	Native forest	Exotic forest	Grass tussock	Exposed bed	Scrub willow	Raupo flax	Other	
Type of river/stream/lake								
Water level	low/normal/high/unknown			Downstream blockage yes/no/unknown			Pollution	nil/low/moderate/high
Wood volume				Current			Organic dams	
RIPARIAN VEGETATION NOTES								

Stability Indices Ratings		
Pfankuch Categories	Value	Notes/General comments
1		
2		
3		
4		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
Total		

Fig. 3.3. General stream survey forms as adapted from M.A.F. data base survey forms.

Table 3.1. Changes during 12 weeks of storage at room temperature of physicochemical variables from water samples collected in 530 ml polyethylene containers from Maori River and Mill Creek, Stewart Island, April 1989.

Maori River

DAYS	pH	ABSORBANCE =	DOC conc.	CONDUCTIVITY (mS m^{-1})	ALKALINITY ($gl^{-1}CaCO_3$)	TEMP.
0	5.8	0.215 =	14.97	10.8	3.4	20.2
7	5.6	0.253 =	16.84	10.4	2.9	21.2
13	6.0	0.231 =	15.77	13.1	2.9	20.5
20	5.5	0.267 =	17.57	11.4	2.0	18.0
28	5.5	0.218 =	15.11	11.2	2.0	20.0
34	5.6	0.265 =	17.47	11.2	2.9	19.0
41	5.9	0.269 =	17.67	14.0	2.5	22.0
84	6.0	0.264 =	17.42	14.0	3.4	
X	5.7	0.248	16.6	12.0	2.8	
+2SE	0.1	0.015	0.8	1.0	0.4	

Mill Creek

DAYS	pH	ABSORBANCE =	DOC conc.	CONDUCTIVITY (mS m^{-1})	ALKALINITY ($gl^{-1}CaCO_3$)	TEMP. °C
0	6.2	0.205 =	14.5	17.4	3.9	20.2
7	6.2	0.211 =	14.8	16.0	4.9	21.2
13	6.6	0.233 =	15.9	15.8	5.9	20.5
20	6.0	0.237 =	15.6	18.5	4.9	18.0
28	6.2	0.201 =	14.3	16.5	5.9	20.0
34	6.1	0.227 =	15.6	16.7	5.9	19
41	6.4	0.227 =	15.6	16.8	5.9	22
84	6.3	0.224 =	15.1	16.6	5.9	
X	6.2	0.219	15.1	16.8	5.4	
+2SE	0.1	0.008	0.4	0.6	0.5	

Table 3.2. Physicochemical characteristics of 78 sites sampled on Stewart Island between August 1987 and November 1989.

	Site name	Date	pH	DOC. (gm-3)	Cond. (mSm-1)	Alka. (CaCO3)	Na+ (mg/l)	Cl- (mg/l)	Pfankuch	Temp. C.
1	Cat Team Camp	31-01-89	5.1	14.29	23.21	2.50	47.59	67.0	47.0	15.0
2	Bay opp.Peg House	30-01-89	6.5	7.49	20.41	4.50	30.80	53.0		15.0
3	Belltoper	30-01-89	5.8	11.25	13.39	2.00	24.83	37.0	41.0	15.0
4	Pegasus sidebranch	30-01-89	5.2	13.01	16.42	1.50	25.29	50.0	76.0	18.0
5	Dam creek(Pegasus crk)	30-01-89	6.0	12.16	8.10	4.00	21.38	23.0	43.0	14.8
6	Upper Kopeka	28-01-89	5.9	10.10	6.37	2.00	11.49	18.0	59.0	12.0
7	Big Glory Bay Stm.	29-11-87	6.7	6.96	13.52					
8	Ogles Creek	25-12-87	7.2	4.94	23.28					
9	Main Rakeahua	08-01-89	6.8	7.09	20.05	13.50			85.0	10.5
10	Hut stream (track)	20-08-87	6.0	8.80	15.23					
11	Hut stream (area 6)	05-12-88	6.6	8.04	19.27	11.34				
12	Stream 1	08-01-89	6.7	10.85	11.76	6.00	20.46	28.0	87.0	
13	Sidebranch (B)	02-03-89	6.7	8.85	17.92	10.50	26.44	50.0		
14	Sidebranch (Site 3)	02-03-89	6.6	10.05	20.16	10.50	29.66	53.0		
15	Table Hill (Biv.)	28-01-89	7.1	9.15	8.64	5.00	13.56	21.0	42.0	11.0
16	Main river (Site 6)	08-01-89	6.8	6.64	20.16	12.50	30.35	46.0	96.0	10.5
17	Sandies Stream	13-11-89	6.2	7.99	13.33	4.05				
18	Site 6 (Rakeahua)1987	20-08-87	6.5	9.80	17.28					
19	Stream 8	08-01-89	7.0	5.23	19.04	14.50	27.59	44.0	57.0	
20	Site 7 (Rakeahua)	20-08-87	6.3	11.30	17.06					
21	Korka Biv.	12-05-89	6.6	11.26	25.29	10.78		71.0	103.5	8.0
22	West slip	17-11-89	6.5	11.31	23.96	8.33		60.0		
23	Doughboy	09-01-89	6.5	10.90	27.00	6.50				
24	Adams hill	10-01-89	6.6	13.21	25.92	7.00	37.39	74.0	75.0	15.0
25	Cavalier	10-01-89	6.6	8.65	43.63	19.00	34.71	64.0	47.5	12.0
26	Upper Wreek creek	26-11-88	7.0	6.74	39.22	17.00	55.18	121.0		13.5
27	Lower Wreek creek	26-11-88	6.9	6.54	43.20	17.50	47.36	106.0		
28	Duck creek (mouth)	26-11-88	7.0	5.38	31.80	26.00	75.87	96.0		
29	Duck creek (upper)	17-05-89	6.8	6.89	31.82	25.48	39.54	78.0		
30	Mason head	11-01-89	6.3	15.22	59.40	7.50				
31	Hellfire beach(south)	11-01-89	6.3	14.07	70.20	6.00	119.55	60.0	94.5	13.5
32	Hellfire beach(north)	11-01-89	6.3	13.91	58.30	8.50	119.55	191.0	62.0	19.0
33	Open creek	11-01-89	6.6	20.09	86.40	5.00	101.15	163.0	66.5	18.0
34	Canyon creek	11-01-89	5.4	20.84	44.50	3.00	160.93	227.0	77.5	14.0
35	Richards Point	11-01-89	5.7	15.67	57.24	4.00	73.57	104.0	84.0	11.5
36	Bensons Peak	12-01-89	5.6	15.07	27.11	1.50	96.56	138.0	75.5	
37	Ladder Creek	13-01-89	4.9	17.08	28.62	2.00	40.00	66.0	65.0	13.5
38	Log pool	13-01-89	5.1	12.81	28.62	1.00	39.54	74.0	60.5	13.0
39	Wilburs Creek	13-01-89	5.7	11.16	23.65	2.50	40.00	74.0	83.0	13.5
40	Waituna turnoff	13-01-89	4.6	19.59	22.05	0.75	32.88	57.0	81.5	13.0
41	Waituna Bay	14-01-89	5.3	23.25	54.00	2.50	38.85	53.0	81.0	13.0
42	Waituna slip stream	14-01-89	6.0	8.24	40.18	3.50	101.16	135.0	100.5	18.0
43	Old Waituna Biv.	13-01-89	4.6	19.79	29.68	0.88	49.89	101.0	58.0	15.0
44	Manuka valley	14-01-89	5.2	10.40	28.62	1.75	40.00	77.0	58.5	12.5
45	Hunters camp	14-01-89	5.0	18.33	30.46	1.00	40.00	69.0	103.0	13.5
46	Broken Stream	15-01-89	6.7	9.5	33.37	20.50	42.76		47.0	13.0
47	Ruggedy Bath Stream	15-01-89	6.7	8.24	52.92	17.00	51.04	110.0	97.0	12.5
48	Corner Stream	15-01-89	6.3	10.45	62.64	6.10	87.36	149.0	100.0	12.0
49	Boulder beach	15-01-89	6.2	15.23	51.94	7.00	108.05	156.0	77.0	11.5
50	Boulder beach(slip)	15-01-89	6.4	8.80	97.52	8.50	99.96	128.0	70.0	13.0
51	Long Harry point	15-01-89	6.3	12.31	46.64	8.00	160.93	255.0	107.0	18.0
52	Long Harry branch	15-01-89	6.5	12.06	47.70	8.50	87.36	177.0	61.0	14.0
53	Ten minute Creek	16-01-89	6.5	11.00	33.70	6.50	87.36		88.0	14.0
54	Rich Windfall Creek	16-01-89	6.8	5.03	27.00	14.50	43.45	85.0	66.0	12.0
55	Lost Clearing Stream	16-01-89	6.7	7.74	27.54	9.00	37.24	71.0	81.0	14.0
56	Smoky Creek	16-01-89	7.1	8.65	23.54	6.25	37.24	64.0	93.0	17.5
57	Yankee River	16-01-89	6.9	7.09	13.50	10.00	34.25	57.0	97.5	13.0
58	1st stream (Y-Xmas)	17-01-89	6.8	6.24	30.24	23.00	19.31	34.0	134.5	14.0
59	2nd stream (Y-Xmas)	17-01-89	6.7	7.59	20.03	20.50	37.01	67.0	64.0	12.0
60	Table Stm. (Y-Xmas)	17-01-89	6.7	8.14	19.93	12.00	41.61	46.0	80.5	11.0
61	Lucky beach (Isop)	17-01-89	6.6	5.28	17.06	11.50	29.20	50.0	73.0	13.0
62	Lucky beach (Main)	17-01-89	6.6	9.05	12.72	9.00	26.44	5.0	105.5	12.0
63	Large river (L-Xmas)	17-01-89	6.8	7.24	12.40	14.00	19.54	35.0	85.5	16.0
64	MtAnglem Tarn(outflow)	18-01-89	6.4	5.64	5.40	3.50	17.24	25.0	83.5	13.0
65	MtAnglem Tarn(main)	18-01-89	7.2	7.69	10.69	13.90	21.38	18.0		
66	MtAnglem Tarn(trib.)	18-01-89	7.0	5.23	22.14	24.00	14.02	21.0	97.0	12.0
67	Old Xmas	19-01-89	7.0	5.43	13.50	23.50	29.20	53.0	83.0	10.0
68	Xmas Murry (1st lg.)	19-01-89	7.0	6.29	11.66	20.50	16.09	28.0	86.0	13.0
69	Xmas Murry (last lg)	19-01-89	7.0	6.29	11.87	16.00	17.24	21.0	77.5	13.0
70	Murry River	19-01-89	7.3	8.14	13.82	16.50	16.09	25.0	92.5	
71	Large Murry-Bung	19-01-89	7.0	5.79	15.12	16.50	18.85	28.0	139.0	15.0
72	Large swingbridge	20-01-89	7.1	8.19	11.99	9.00	20.46	35.0	94.5	13.0
73	Maori sidebranch	28-11-89	6.5	10.95	13.33	8.91	18.85	35.0	113.0	12.0
74	Maori Main upper	28-11-89	6.3	11.71	11.42	6.89				
75	Maori Biv	06-04-89	6.6	10.60	13.55	8.90	17.24	41.0		
76	Maori estuary	23-08-89	6.7	5.86	29.32					
77	Little river	21-02-88	6.8	6.03	16.50					
78	Mill creek (upper)	06-04-89	6.7	7.24	21.39	21.80	23.22	45.00		

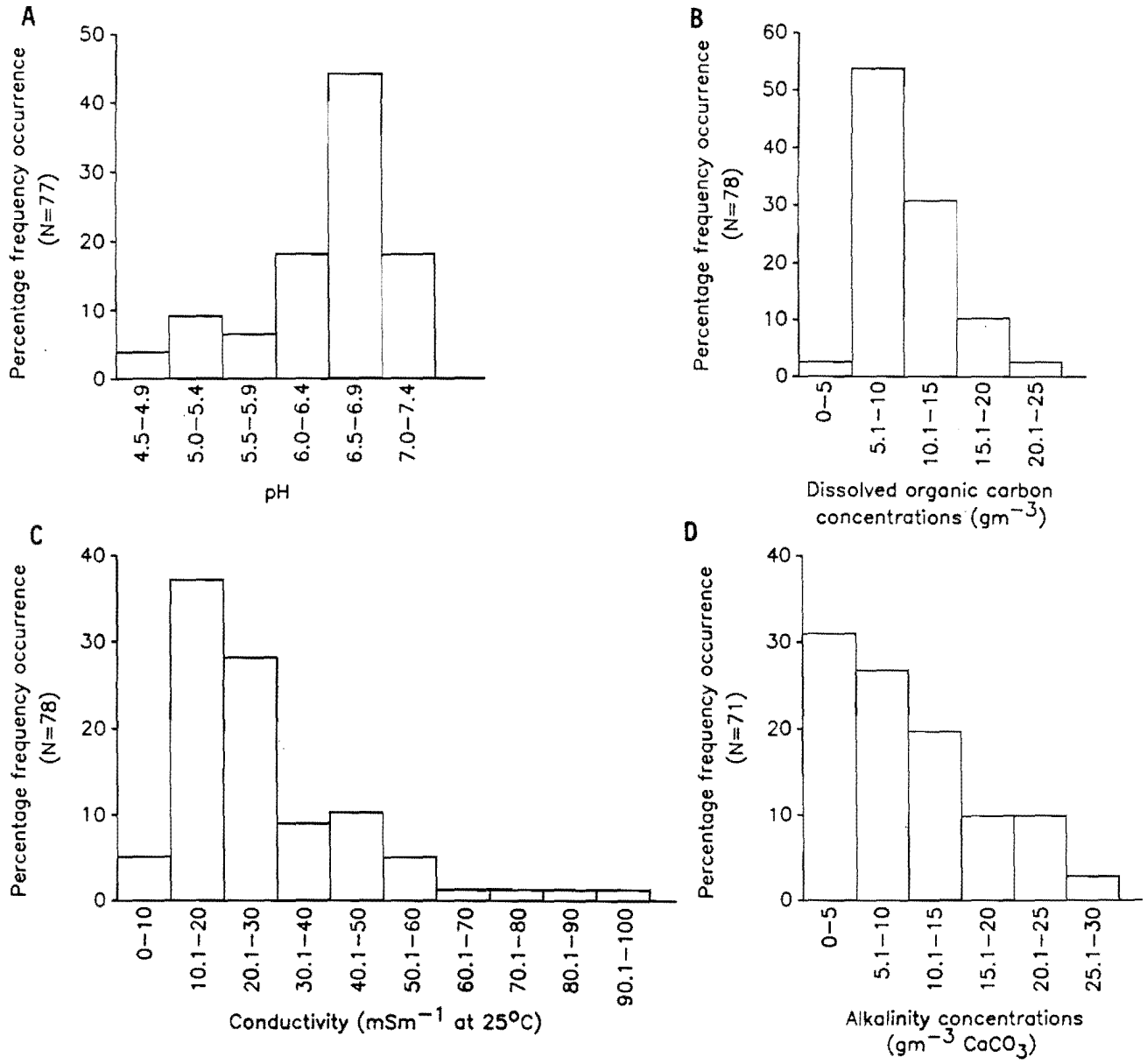


Fig. 3.5. Percentage frequency occurrence of various water chemistry parameters measured from some Stewart Island streams between August 1987 and November 1989. A) pH, B) DOC concentration, C) conductivity, D) alkalinity.

0.01, Table 3.3) suggests acidity is largely controlled by humic substances, as appears to be the case on the west coast, South Island (Collier and Winterbourn 1987). However, the strong positive correlation of pH with alkalinity (r^S = 0.73, $P < 0.01$, Table 3.3) is also indicative of the relatively poor bicarbonate buffering capacity of many Stewart Island streams.

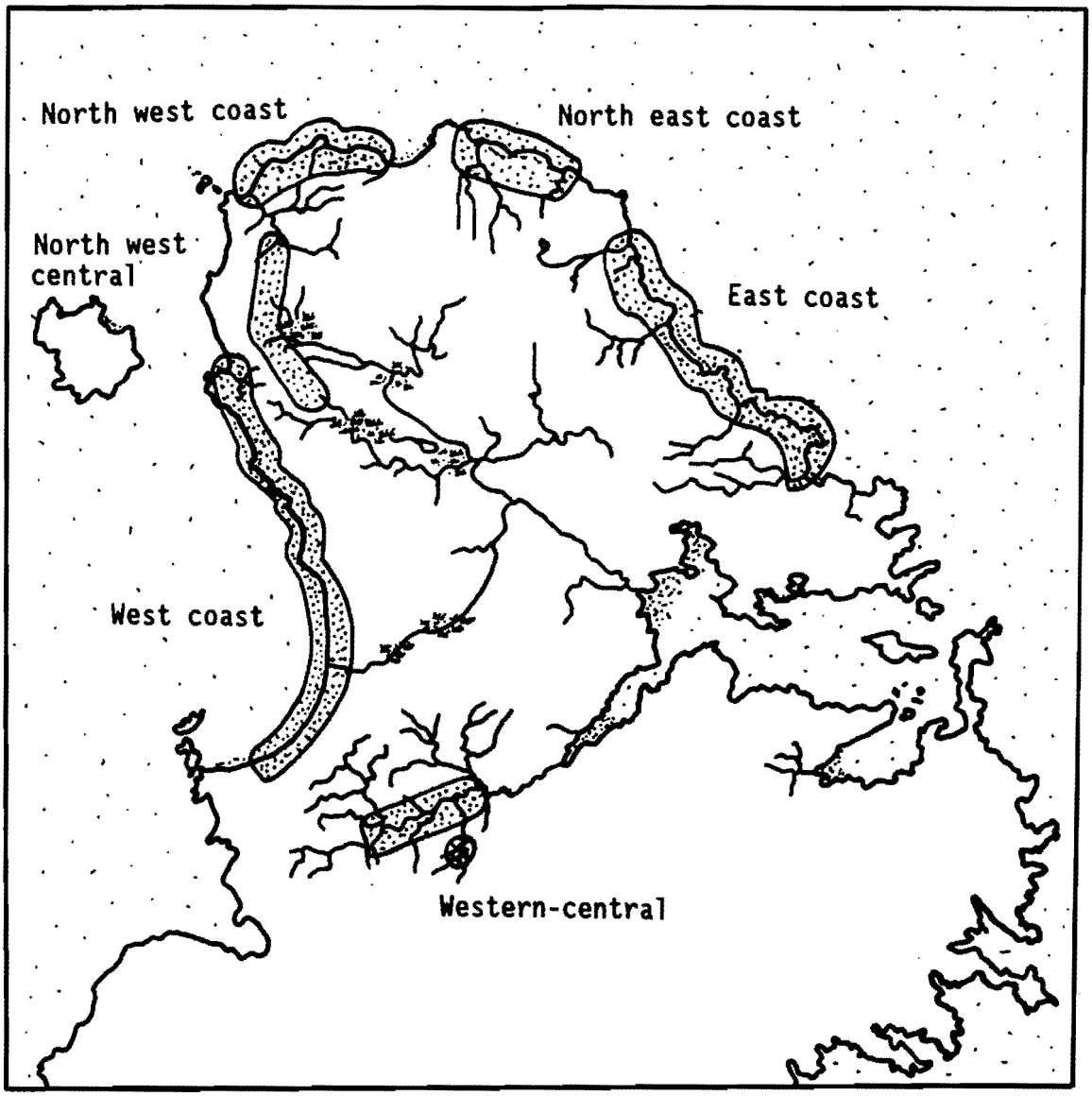
Conductivity (5.4 to 97.5 mS m^{-1} at 25^0C, Fig. 3.5C) was up to an order of magnitude greater than values reported by Winterbourn and Collier (1987) for acid brown water streams with similar pH and DOC concentrations in South Westland (South Island), and alkalinity (0.7 to 23.5 gm^{-3} $CaCO_3$, Fig. 3.5D) fell within the lower half of the range of values reported by them. In the case of conductivity, a coastal (saline) influence is apparent. Concentrations of sodium (Na^+) and chloride (Cl^-) ions in water samples from northern and central Stewart Island indicate that salts deposited by prevailing westerly winds, blowing off the sea, contribute to the high conductivities of coastal streams (Fig. 3.6). Wind blown salt was also implicated by Veblen and Stewart (1980) and Wilson (1987) as influencing coastal die back of podocarp forest around the island. In coastal, northern Stewart Island, two distinct groups of streams occur. The first group includes all streams on the northwest side between Site 30 (Mason Head) and Site 53 (Long Harry), including streams sampled on the eastern side of the Ruggedy Mountains (Fig. 3.1). These streams are short (1^{st} to 4^{th} order), acidic, brown water streams (pH 4.6 to 6.7) with moderate to high conductivity (22.1 to 97.5 mS m^{-1} at 25^0C) and DOC concentrations (8.5 to 23.3 g m^{-3}), and moderate to low alkalinity (0.8 to 20.5 g m^{-3} $CaCO_3$). The second group includes east coast streams from Site 54 (Smoky Beach) to site 72 (near Bungaree), but not Site 64 the outflow of Mt. Anglem Tarn. These streams are predominantly circumneutral (pH 6.6 to 7.3) clear water streams with low to moderate DOC concentrations (5.0 to 9.1 g m^{-3}), alkalinity (6.3 to 23.0 g m^{-3} $CaCO_3$) and moderate to high conductivity (11.7 to 30.2 mS m^{-1} at 25^0C).

Elsewhere on the island, an east-west gradient in water chemistry is not apparent, and in the interior, streams range from clear circumneutral to acidic brown waters.

Winter temperature minima at "Stream One" and "Hut Stream" (Fig. 3.4) were 2-3^0C lower than values reported by Collier and Winterbourn (1987)

Table 3.3. Correlations (r) between various parameters measured from some Stewart Island streams in January 1989 (n = 36, * = P < 0.1, ** P < 0.05, *** P < 0.01).

	pH	DOC cencentration	Conductivity	Alkalinity	Percentage moss cover	Pfanckuch Stability	Stream bed stability	Width	Substrata	Current
pH	1.00									
DOC cencentration	-0.74 ***	1.00								
Conductivity	-0.28	0.52	1.00							
Alkalinity	-0.73 ***	-0.50 ***	-0.08	1.00						
Percentage moss cover	-0.38 **	0.15	-0.22	-0.44 ***	1.00					
Pfanckuch Stability	0.29	-0.09	-0.05	0.26	-0.67 ***	1.00				
Stream bed stability	0.20	-0.12	-0.18	0.20	-0.58 ***	-0.88 ***	1.00			
Width	0.08	0.09	-0.24	0.01	-0.10	0.21	0.11	1.00		
Substrata	-0.08	-0.10	-0.24	-0.32 **	0.67 ***	-0.62 ***	-0.44 ***	0.09	1.00	
Current	-0.24	0.02	-0.41 **	-0.43 ***	0.36 **	-0.10	0.08	0.39 **	0.58 ***	1.00



	Na^+ (mg l^{-1})	Cl^- (mg l^{-1})	Conductivity (mS m^{-1})
Western-central	14 - 30	21 - 53	8.6 - 20.1
West coast	40 - 160	78 - 227	31.8 - 864
North west central	33 - 51	53 - 110	22.1 - 33.4
North west coast	34 - 161	57 - 255	23.5 - 97.5
North east coast	17 - 41	25 - 67	12.4 - 30.2
East coast	14 - 29	21 - 53	11.0 - 29.3

Fig. 3.6. Geographical variation in sodium and chloride ion concentrations and conductivity of streams of northern Stewart Island.

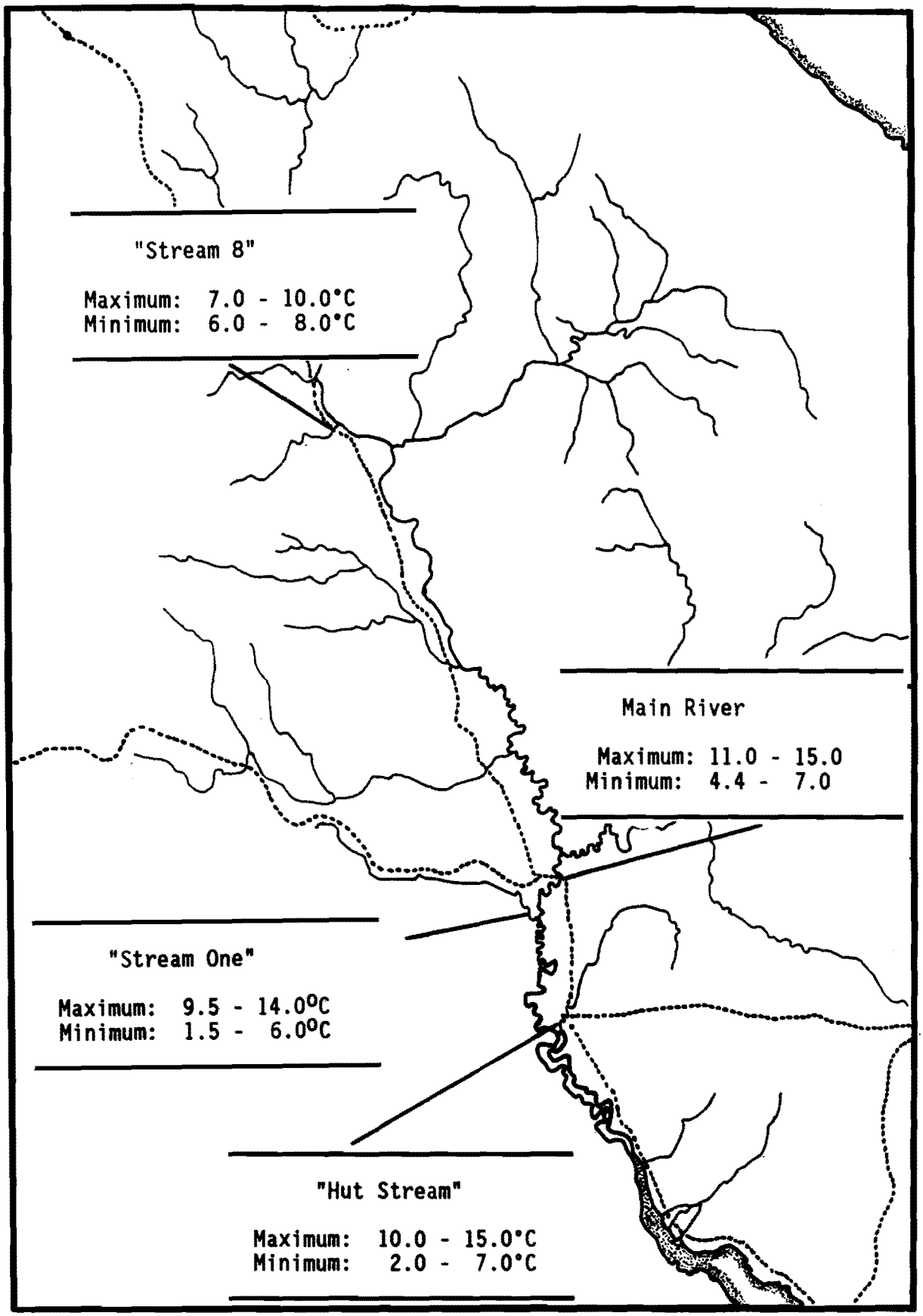


Fig. 3.4. Range of minimum and maximum temperature recorded on thermometers set at four sites in the Rakeahua River and read and reset on four occasions between April and December 1989.

for small South Westland streams at similar altitude, but values from the mainstem of the Rakeahua River and "Stream 8" were comparable to theirs. Spot temperatures (Table 3.2) ranged from 10.5-19^{o}C and reflected general weather patterns such that the highest temperatures were recorded on warm, sunny, summer days.

Streams flood regularly as a result of the moderately high, frequent rainfall and high soil moisture levels. Like Wilson (1987) my observations over the last three years indicate that streams are capable of sustaining periodic flood flows several metres above normal levels, with little change in water colour. Physical effects of flood events on stream beds appear to be relatively slight, especially in streams flowing through rolling hill country and across the Rakeahua flood plain. Most stream beds are moderately stable and little sustrate movement occurs except in heavy floods. Pfankuch substrate stability scores from 56 sites ranged from 41 to 139, although 80 percent of all sites measured were below 100. A total of 56 percent rated "fair" (between 76 and 115) and 40 percent rated "good" (ie., < 76). Only two sites, Yankee River and Murry River had ratings over 115 (poor). Both contain large amounts of gravel, which in the case of Murry River probably originated from a large slip on little Mount Anglem, at the head of the river (Wilson 1987). These two streams are the closest equivalents to an unstable braided river on Stewart Island. However, even they appear to be relatively more stable than mainland braided rivers, as large, woody debris is present, and forested upper banks and steep valley sides ensure rivers channels do not meander.

In an earlier paper (Chadderton 1988) I suggested that many Stewart Island streams were probably very unstable. This conclusion was based on observations made in the lower reaches of the Rakeahua and Freshwater Valleys which have weak upper banks, but clearly, it does not apply to conditions on the island in general.

Water turbidity of streams on Stewart Island is generally low, and during floods little new sediment enters them. For example during the "Southland floods" (26/27 January 1984, when 135 mm of rain fell in 24 hours in nearby Invercargill) discharge levels in the Freshwater Valley were high but little silt was carried in suspension (Ron Tindal Department of Conservation, pers. comm. in Wilson 1987). Tindal noted that although the river level reached the spouting on the hut at

Freshwater Landing, some 3-4 m above normal, no silt was deposited, 'the hut floor and tables were just wet'. The time taken for the flood to top the river bank was approximately 14 hours after the rain began; it peaked after 26 hours, and was below the banks again 38 hours later.

What silt is carried in solution, probably originates from minor slips on the upper banks. Wilson (1987) suggested that much of the recent alluvium on valley floors may have come from very occasional, but substantial landslips that have scarred the steep slopes of most hills and mountain ranges on the island. The apparently low silt loads carried by streams is probably a consequence of predominantly granitic rocks of Stewart Island. This would be consistent with the North American studies of Johnson and Reynolds (1977) who found that the lowest dissolved solids concentrations (12.8 to 18.6 g m^{-3}) occurred in streams draining basins underlain by granitic rock, and that basins containing metamorphic and sedimentary bedrock had substantially higher concentrations of dissolved solids (32 to 224 g m^{-3}).

On Stewart Island, many streams are notable for the presence of thick bryophyte carpets that can cover many kilometres of stream bed (Wilson 1987). Bryophyte cover can reach 100 percent in some circumstances, but 50-80 percent cover is more typical, particularly in cooler, head water streams and larger streams to the south. Mosses acquire surprising luxuriance, and Martin (1949) recorded some aquatic plants up to 35 cm long. *Cryptochila pseudocclusa* and/or *C. grandiflora* and/or *Blindia immersa* appear to be the predominant species in the dark green bryophyte turf of most streams, although on waterfalls they are joined or largely replaced by *Fissidens rigidulus* and *Thamnobryum pandum* (Wilson 1987). Further species of moss and liverworts are listed by Martin (1949, 1950). As expected, percentage moss cover was negatively correlated with Pfankuch (1975) scores and positively correlated with substrate size (Table 3.3).

Filamentous green algae can also be common at times, particularly in open, coastal streams, in the warmer, summer months. Debris dams also occur frequently in headwater streams, and the meandering lower reaches of some rivers are choked with trees (see Plate 5.2A, Chapter 5). Leaf packs are commonly associated with back eddies and pools in these reaches, whereas less leaf debris was seen in the steeper, faster flowing streams of the north east coast. In the latter streams, the small amounts of debris present was mainly fresh leaf material, and tree trunks that

generally lay parallel with the stream channels. Because of this orientation, their effectiveness as debris retention devices was limited.

In summary, Stewart Island streams are probably most similar to those present on the west coast South Island, than in other parts of New Zealand. DOC concentrations, pH, and alkalinity values recorded on the island fell within the range of values recorded by Winterbourn and Collier (1987) for Westland streams, but conductivity values were on average higher. Furthermore, stream stability (sensu Pfankuch 1975) (and moss cover) was generally higher, and silt loads were probably lower than in many west coast streams.

CHAPTER 4

THE INVERTEBRATE FAUNA OF STEWART ISLAND

GENERAL INTRODUCTION

The outstanding features of the New Zealand aquatic invertebrate fauna are the very high degree of endemism at all taxonomic levels and the absence or low diversity of many groups common elsewhere in the world (Forsyth and Lewis 1987).

The benthic faunas of stony streams are dominated by insects especially species of Ephemeroptera, Plecoptera, Trichoptera, and Diptera (Winterbourn 1987). At forested and open sites, in unmodified streams, the faunas usually include a large number of opportunistic, "common core" species (Winterbourn 1987) that show broad ecological requirements, and poorly synchronized life history patterns. However, with loss of forest cover, increasing catchment development and water enrichment, a reduction in species diversity, but not necessarily density may occur (Winterbourn 1981, Penny 1985, Quinn and Hickey ms). Under such conditions, Plecoptera may be largely eliminated (*Stenoperla* spp. and some species of *Zelandobius* are the major exceptions), and the Ephemeroptera is likely to be represented exclusively by species of *Deleatidium* (Winterbourn 1981). A reduction in caddisfly diversity is also found frequently, although the densities of some algal grazers and collector-browsers like *Oxyethira albiceps*, *Pycnocentria evecta*, *Pycnocentrodes* spp., and *Olinga feredayi* (Winterbourn 1981, Penny 1985) may increase. Similarly, Chironomidae, Mollusca (*Potamopyrgus*, *Physa*, and *Sphaerium*), Oligochaeta (Naididae, Lumbriculidae, and Tubificidae), and *Paracalliope fluviatilis* (Amphipoda) are often numerically more abundant in developed catchments or under conditions of moderate enrichment.

Almost all the once extensive lowland forest in New Zealand has been cleared by Polynesian and European settlers (McGlone 1980), and catchments of most lowland rivers and streams now represent highly modified environments (Winterbourn 1987). Naturally forested, unpolluted lowland streams flowing across unmodified flood plains are essentially unknown because of the effects of agricultural and urban development. Consequently, if a distinct lowland invertebrate fauna existed prior to human colonisation, it is almost certainly extremely rare now.

Distinct from the widely distributed "common core" of stream invertebrate species are a number of species that have more restricted geographic distribution patterns, presumably because they have more specific environmental relationships. For example, local endemism is shown by the oeconescid, *Zelandopsyche ingens* that is restricted to South Island beech forest (Winterbourn and Davis 1976), the blephariceri d, *Neocurupira chiltoni* that occurs only on Banks Peninsula (Craig 1969), and four species of *Cryptobiosella* that have highly localised distributions (Henderson 1983). Other groups of species are restricted to one of the two main island. For example, *Latia neritoides*, and *Orthopsyche* occur only in the North Island, whereas *Nannochorista philpotti* is known only from the South (Winterbourn 1987). Likewise, the greatest diversity of Leptophlebiidae is found in the north of the North Island, whereas species richness of Plecoptera is greatest in the west of the South Island.

PART I

THE TAXONOMIC COMPOSITION OF THE BENTHIC INVERTEBRATE FAUNA

INTRODUCTION

In the highly diverse landscape of Stewart Island where lowland forest is intact and streams are often forested from source to mouth, unique stream invertebrate assemblages might be expected to occur. Furthermore, Stewart Island's relative isolation may have resulted in the presence of some local endemics. The absence of anthropogenic disturbances over much of the island, and an absence of introduced fishes (at least until extremely recently) also means that the fauna present now may be representative of that which was present in lowland streams on the southern mainland, prior to human colonisation.

In this chapter, the invertebrate fauna is characterised and notes on abundance, distributions and habitat patterns are provided.

METHODS

A comprehensive faunal list was drawn up from all invertebrate samples collected between August 1987 and December 1989. Hence, it

encompasses early survey work (Chadderton 1988), data from a more extensive survey (Part II), and data collected during leafpack colonisation and fisheries work (Chapters 5, 6 and 7). About 80 sites in 1st to 6th order streams were sampled; a summary of locations is given in Fig. 4.01.

Field observations were also made at a further 34 sites where I searched principally for *Austridotea* spp., *Archichauliodes diversus*, *Hydroptilidae*, and *Conoesucidae*. The former are unusual isopods rarely seen in mainland New Zealand, and the latter three taxa are common on the North and South Islands but appeared to be absent from Stewart Island (Chadderton 1988).

Distributional data for *Austridotea* and the freshwater shrimp *Paratya curvirostris* were collected from spot benthic samples, by sweeping under banks and through marginal vegetation, and by turning over rocks or woody debris to check for their presence. These samples were examined in the field and then discarded. Records of invertebrates collected in fish traps were also noted.

Invertebrates in preserved samples were usually identified under a binocular microscope to operational taxonomic units (OTUs) which in most cases were species or probable, but unidentifiable species, and sometimes genera. Exceptions were the Chironomidae which were not separated below family, Oligochaeta below class, Acarina below order and Nematoda below phylum.

Taxonomic works used for identification were McFarlane (1951), Winterbourn (1973), Chapman and Lewis (1976), Cowley (1978), Towns (1983), and Winterbourn and Gregson (1989).

Except where stated, relative abundance and distributional data apply to the 45 survey sites described in Part II and references to top five taxa relate to the list given in Table 4.02.

The top five taxa list includes any taxon that was one of the five most abundant at any site. In Table 4.02 total number of occurrences, refers to the number of sites at which the taxon occurred irrespective of abundance.

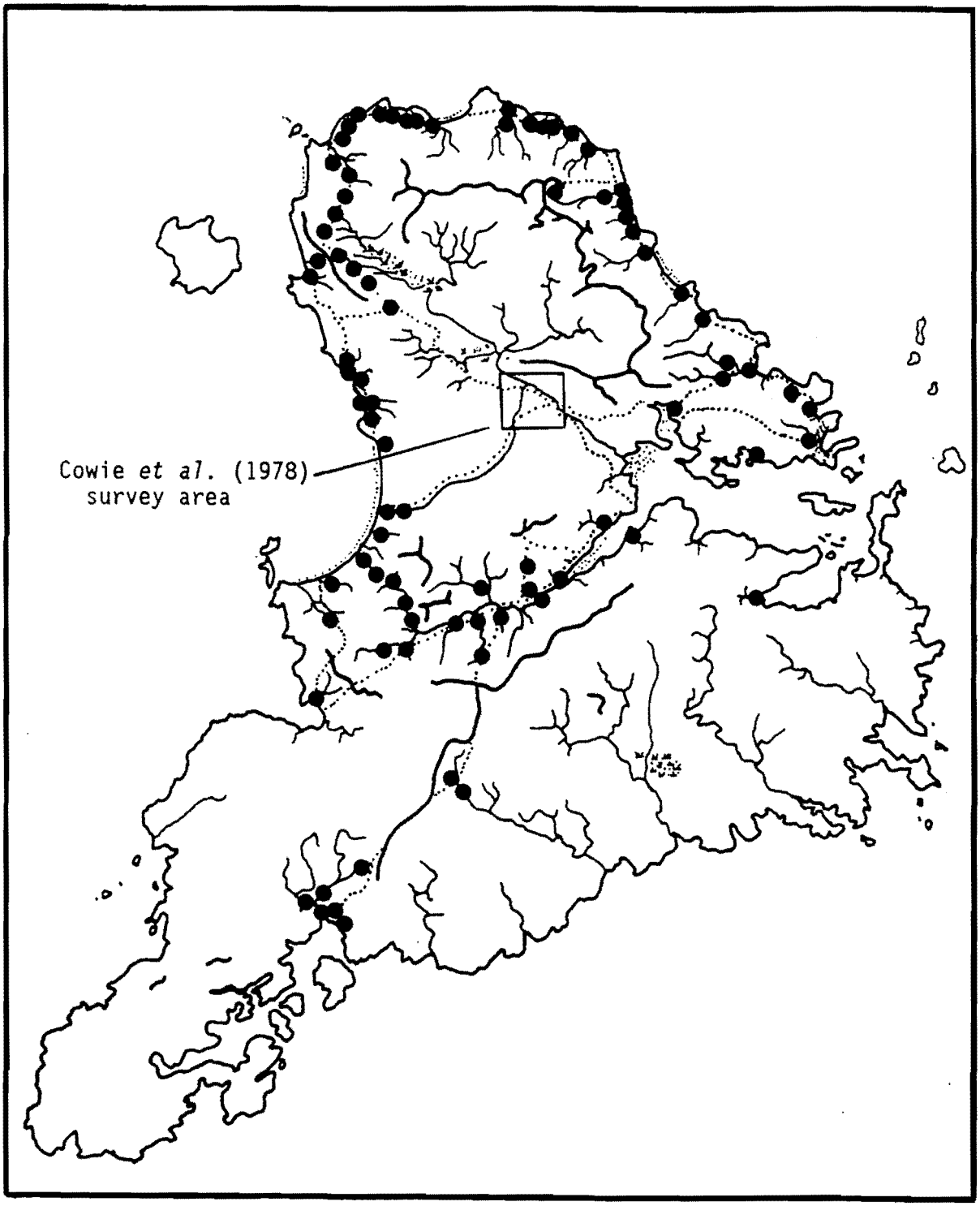


Fig. 4.01. Stewart Island invertebrate survey sites (August 1987 to December 1989).

RESULTS AND DISCUSSION

A total of 113 aquatic invertebrate taxa were identified from Stewart Island, of which most (81 %) were Insecta (Table 4.01). The most diverse taxa were the Trichoptera (32 OTUs), Diptera (24), Plecoptera (13), Ephemeroptera (10), and Amphipoda (7).

Ephemeroptera

Ten species of mayfly were collected including seven species of Leptophlebiidae. It is not possible to identify *Deleatidium* species, although informal lillii and myzobranchia groups were recognised. Baetidae and Ephemeridae were not collected and only two species of Siphlonuridae were found.

Only *Deleatidium* spp., *Austroclima sepia* and *Coloburiscus humeralis* were widespread and present in the list of top five taxa (Table 4.02); all other species were rare or restricted in their distributions. Of the latter, the occurrence of *Mauiulus luma* is of note, as its known distributional range is extended substantially beyond the previous southern-most records at Franz Josef Glacier (Collier 1988).

Collections of *Zephlebia spectabilis* were also interesting because it was generally found in association with woody debris and leaf packs, especially in the slow flowing reaches of the lower Rakeahua River. More commonly it has been found in slow flowing stony habitats within forested streams (Towns 1983), including the Blue Duck Stream, a small coastal creek north of Kaikoura (M.J. Winterbourn pers. comm.).

Plecoptera

Thirteen species were collected including undescribed species of *Acroperla* and *Zelandobius*. The family Gripopterygidae was well represented and all New Zealand genera except *Nesoperla* were recorded. In contrast, Notonemouridae were represented only by *Cristaperla fimbria*, and even it was rare although found at numerous sites.

Austroperla cyrene, *Zelandobius confusus* and *Zelandoperla agnestis* and/or *fenestrata* were all widespread (i.e., present in over 50 % of invertebrate samples) and are members of the top five taxa lists for Stewart Island (Table 4.02).

The undescribed species of *Acroperla* has distinctive early instar larvae. They possess flanges on each thoracic segment, similar to those of *Megaleptoperla* spp. and *Apteryoperla tillyardi*, but they are more

Table 4.01. Invertebrates collected from Stewart Island freshwater ecosystems, principally running waters, August 1987 to December 1989.

EPHEMEROPTERA
Leptophlebiidae
*Deleatidium*spp.
Mauiulus luma
Zephlebia versicolor
Zephlebia spectabilis
Neozephlebia scita
Austroclima sepia
Austroclima jollyae

Oligoneuriidae
Coloburiscus humeralis

Siphlonuridae
Nesameletus sp.
Ameletopsis perscitus

PLECOPTERA
Eustheniidae
Stenoperla prasina
Austroperlidae
Austroperla cyrene
Gripopterygidae
Megaleptoperla grandis
Zelandoperla fenestrata
Zelandoperla agnestis
Zelandoperla decorata
Zelandobius confusus
Zelandobius furcillatus
Zelandobius unicolor
Zelandobius sp.
Acroperla trivacuata
Acroperla sp.
Notonemouridae
Cristaperla fimbria

ODONATA
Coenagrionidae
Xanthonemis zealandica
Lestidae
Austrolestes colensonis
Cordulliidae
Procordulia smithi

TRICHOPTERA
Hydrobiosidae
Hydrobiosis parumbripennis
Hydrobiosis umbripennis
Hydrobiosis ?harpidiosa
Hydrobiosis ?silvicola
Hydrobiosis ?clavigera
Costachorema brachyptera
Costachorema ?psaroptera
Costachorema ?xanthoptera
Costachorema callista
Psilochorema ?bidens
Psilochorema ?tautoru
Psilochorema ?nemorale
?Hydrochorema tenuicaudatum
?Hydrochorema crassicaudatum
Tiphobiosis sp.

Philopotamidae
Hydrobiosella stenocerca

Leptoceridae
Hudsonema aliena
Hudsonema amabalis
Triplectides dolichos
Triplectides cephalotes

Hydroptilidae
Oxyethira albiceps

Helicopsychidae
Helicopsyche sp.
Rakiuru vernale
(?)Ecnomidae/Psychomyiidae
(?)*Ecnomina zelandica/Zelandoptila moselyi*

Calocidae
?Pycnocentrella eruensis

Hydropsychidae
Aoteapsche raruraru
Aoteapsyche ?tepoka

Oeconesidae
Pseudoeconesus sp.
Unidentified species

Polycentropodidae
Polyplectropus puerilis

Conoesucidae
Pycnocentria sp.

Helicophidae
Zelolessica meizon

DIPTERA
Ceratopogonidae
Unidentified species

Chironomidae
Tanypodinae sp
Chironominae
Tanytarsini sp.
Chironomus sp.

Muscidae
Unidentified species

Tipulidae
Zelandotipula sp.
Limonia nigrescens
Aphrophila neozelandica
Aphrophila sp.
Hexatomini sp.
Paralimnophila skusei
Eriopterini
Molophilus sp.
Unidentified species

Simuliidae
Austrosimulium sp.

Empididae
Species A.
Species B.

Blephariceridae
Neocurupira tonnoiri

Tanyderidae
Mischoderus sp.
?Unidentified species

Psychodidae
Unidentified species

Stratiomyidae
Unidentified species

Dixidae
Nothodixa

Unknown aquatic diptera

COLEOPTERA
Elmidae
Hydora species

Helodidae
Species A
Species C
Hydraenidae
Orchymontia bidentata

Hydrophilidae
Unidentified species
Staphylinidae
Unidentified species

MECOPTERA
Nannochorista philpotti

LEPIDOPTERA
Hygraula nitens

HEMIPTERA
Anisops assimilis

AMPHIPODA
Eusiridae
Paraleptamphopus caeruleus
Paraleptamphopus subterraneus
Paraleptamphopus sp.
Paracalliope sp1.
Paracalliope sp2.

Hyalellidae
Chiltonia rivertonensis

?Orchestia species

ISOPODA
Idoteidae
Austridotea benhami
Austridotea annectans

Flabellifera
Paravireia (?)typica

Phreatoicidae
Unidentified species

Styloniscidae
Styloniscus otakensis

DECAPODA
Atyidae
Paratya curvirostris

Parastacidae
Paranephrops zealandicus

GASTROPODA
Hydrobiidae
Potamopyrgus antipodarum
Potamopyrgus estuarinus

Sphaeriidae
Sphaerium noveazealandiae

TURBELLARIA
?Neppia montana

ACARINA

NEMATOMORPHA

COPEPODA
Harpacticoida

OLIGOCHAETA

Table 4.02. Numbers of occurrences and top 5 placings of any taxon that was one of the 5 most abundant taxa at at least one of 45 sites surveyed between December 1988 and November 1989. The total number of sites at which each top five taxon occurred is also given.

	Total No. of occurrences	Times in top-5	Top 5 placing 1	2	3	4	5
Species							
Ephemeroptera							
Deleatidium spp.	42	25	3	5	9	4	4
Coloburiscus humeralis	17	6	0	2	3	0	1
Austroclima sepia	21	3	0	1	0	1	1
Plecoptera							
Stenoperla prasina	12	1	0	0	0	0	1
Austroperla cyrene	28	2	0	0	1	0	1
Zelandobius confusus	38	12	0	1	1	2	7
Zelandoperla spp.	30	7	1	1	2	3	0
Trichoptera							
Costachorema callista	5	1	0	0	0	0	1
Hydrobiosidae (Early Instar)	38	4	0	0	0	2	2
Oxyethira albiceps	20	5	0	0	2	0	3
Hydrobiosella stenocerca	28	10	0	1	2	2	5
Aoteapsyche raruraru	14	2	0	0	0	1	1
Helicopsyche sp.	7	3	0	0	2	0	1
Rakiura vernale	17	1	0	0	0	0	1
Zelolessica meizon	18	1	0	0	0	0	1
Coleoptera							
Scirtidae sp. A	27	2	0	0	0	0	2
Scirtidae sp. B	17	5	0	1	2	2	0
Elmidae *Hydora* sp.	19	2	0	0	0	2	0
Crustacea							
Austridotea benhami	8	3	0	0	0	1	2
Chiltonia rivertonensis	40	29	19	3	3	3	1
P.subterraneus	20	5	0	3	0	1	1
Paracalliope sp. 1	10	2	1	1	0	0	0
Paracalliope sp. 2	1	1	1	0	0	0	0
Diptera							
Chironomidae	43	42	13	16	7	4	2
Simuliidae	41	14	0	2	4	3	5
Ceratopogonidae	16	2	0	0	0	0	2
Unidentified diptera	5	1	0	0	1	0	0
Other							
Potamopyrgus antipodarum	20	11	1	3	3	3	1
Acarina	22	2	0	0	0	1	1
Collembula	10	1	0	0	0	1	0
Nematode	21	2	0	0	1	0	1
Oligochaeta	43	23	5	4	3	8	3

pronounced and ornate. This species was widespread (collected at 23 of 45 sites (51 %)) although it was never abundant, and usually only two or three early instar larvae were collected from any site. Later instar larvae appear to be semi-terrestrial like those of *Acroperla trivacuata*, and many were collected from the lower banks of streams up to 0.5 m above the water line.

Some early instars of a "hairy" *Zelandobius* spp. were also collected. They were not as "hairy" as the species currently being described by Russell Death (ms) and mentioned by Winterbourn and Gregson (1989).

Trichoptera

Several Trichoptera species have previously been collected from Stewart Island (McFarlane 1973, Michaelis 1973, McFarlane and Cowie 1981, Patrick *et al.* 1989). I recorded 34 taxa (OTUs), almost half of which were Hydrobiosidae, but species names could only be assigned tentatively to ten of them because differences in some larvae are small and positive associations with adults were not made. In particular, larvae of *Trailochorema* species are unknown and apparently they are similar to *Hydrochorema* (McFarlane and Cowie 1981) which may also occur on the island.

Hydrobiosidae were widespread and occurred in most invertebrate samples (38 of 45, Table 4.02). Most were early instar larvae which could rarely be identified to species (or often genus).

The philopotamid, *Hydrobiosella stenocerca* was the most widespread and abundant trichopteran. It was present at 62 % of sites and was one of the top five taxa five times.

Cased caddis larvae were poorly represented in collections and were usually uncommon. The major exception was *Oxyethira albiceps*, which was found at 44 % of sites, and was a top five taxon on five occasions (Table 4.02). *Zelolessica meizon* and *Rakiura vernale* were almost as widespread (40 and 38 % of sites, respectively), however, they were usually uncommon and were top five taxa only once and twice, respectively (Table 4.02). Henderson (in Patrick *et al.* 1989) recorded adults of *Oxyethira albiceps* and *Paroxyethira hendersoni* from Mason Bay, but I did not find larvae of the latter at any site.

Four leptocerids were recorded from Stewart Island. *Triplectides cephalotes* was taken from a dune lake at Mason Bay where adults had been collected by Patrick *et al.* (1989). The specific identities of the other *Triplectides* larvae were uncertain. McFarlane and Cowie (1981) stated that only *T. dolichos* was known from Stewart Island, but as larvae cannot be distinguished from the common New Zealand species *T. obsoleta* this has still to be confirmed. Henderson (in Patrick *et al.* 1989) also recorded *Oecetis unicolor* from the Mason Bay area, but I did not find this species in my surveys.

Only one conoesucid was recorded (*Pycnocentria* sp.) and it was neither widespread (14 sites) nor abundant. Its identity is also uncertain, as although heads of my specimens were similar to those of *P. sylvestis*, the granular pattern was not as pronounced as in specimens collected by Ian Henderson (pers. comm) from Nelson. Case shape and case construction were also unlike those he had seen in *P. sylvestris* larvae. Therefore it may be a new species. Larvae collected from the Freshwater Valley (Stewart Island), and identified by Cowie *et al.* (1978) as *P. sylvestris* were probably this species, and so might be the larvae identified as *Pycnocentrella eruensis* by Chadderton (1988).

Two early instar oeconesid larvae were collected (Table 4.01) but although too small to be identified, knowledge of their presence considerably increases the known southern distribution limits of this family. A single specimen belonging to either the Ecnomidae or Psychomyiidae was found, and larvae of a helicophid, *Zelolessica* were relatively common. In an earlier account, (Chadderton 1988), I recorded *Z. cheira* from Stewart Island, but close examination of further specimens suggested that they may actually be *Z. meizon*. This was confirmed by Ian Henderson (pers. comm.) who noted that although cases were more typical of *cheira*, head shape and size were characteristic of *meizon*.

Diptera

The Diptera was a diverse group dominated by Chironomidae, Tipulidae and Simuliidae. Chironomidae and Simuliidae were both widespread and important components of the fauna. They occurred at 96 and 91 % of all sites and were frequently top five taxa (Table 4.02). Of the other Diptera found on Stewart Island (Table 4.01), records of *N.tonnoiri* (Blephariceridae) and the Tanyderidae are probably most noteworthy.

On Stewart Island, *N. tonnoiri* has a limited distribution. It was collected only from a few lowland sites and was not found at sites above 100 m altitude even though many of these fell within the altitudinal range (150 to 800 m a.s.l.) noted by Craig (1969) for this species on the mainland.

Members of the Tanyderidae are regarded as the most primitive of all living Diptera. About 36 species are known throughout the world, half of them from Australasia alone (Exner and Craig 1976). Although rarely collected on the mainland, tanyderids appear to be widely distributed in stony and soft bottomed streams in New Zealand (Winterbourn and Gregson 1989). This also appears to be the case on Stewart Island where larvae of *Mischoderus* were collected from six sites in various parts of the island. Larvae of a second dipteran that may also be a tanyderid (R.L.C. Pilgrim pers. comm.) were taken at a further seven sites.

Coleoptera

Six families of Coleoptera were found in Stewart Island's freshwaters. Of these a species of Scirtidae (sp. A) (Helodidae), was widespread and present at 60 % of sites. Another larval scirtid (sp.C) and an elmid *Hydora* sp. were less widely distributed (42 and 38 % of sites, respectively) although they were often more abundant and were top five taxa (Table 4.02) five and two times, respectively.

An hydraenid, *Orchymontia bidentata*, was also relatively common (see Group 2, Part II, Fig. 4.08.).

Others insects

Of the other groups, larvae of the mecopteran, *Nannochorista philpotti* and the lepidoteran, *Hygraula nitens* are probably most notable.

N. philpotti is the only New Zealand scorpionfly with aquatic immature stages (Pilgrim 1972). Although only recorded from the South Island (Winterbourn and Gregson 1989), it has been collected from Stewart Island before (R.L.C. Pilgrim pers. comm.). Larvae were collected at three sites, although its preferred habitats, fine organic deposits out of the current particularly in backwater regions or along the margins of streams (Winterbourn and Gregson 1989), were not extensively sampled.

Hygraula nitens is the only New Zealand moth with an aquatic larva. Larvae are common on macrophytes in ponds and lakes throughout much of

New Zealand (Winterbourn and Gregson 1989) and the only specimen collected on Stewart Island was from a small dune lake at Mason Bay, where it was associated with the pondweed *Potamogeton*.

Isopoda

Four aquatic species were collected (*Austridotea benhami*, *Austridotea annectans*, *Paravireia typica* and an indeterminate species of Phreatoicidae). The *Austridotea* species are of particular interest.

The distributions and biology of the two species of *Austridotea* are poorly known and only a few populations have been reported from New Zealand (Chilton 1892, Nicholls 1937, Marshall 1974, Chapman and Lewis 1976, Ryan 1982). Nevertheless, one species, *Austridotea annectans*, was originally collected and described from Stewart Island (Nicholls 1937), and was later recorded from the Leeston Drain (Marshall 1974) and Lake Ellesmere (Ryan 1982) in the South Island. In contrast, *A. benhami* was described from specimens collected near Dunedin (Nicholls 1937) and was also found on Stewart Island recently (Chadderton 1988). Nicholls (1937) collected a single specimen of *A. benhami* from a mud filled hollow in Ross Creek (Dunedin), however, isopods collected by Chilton (1892) and identified as *Idotea lacustris* were actually *A. benhami* (Nicholls 1937). From Chilton's records it appears that *A. benhami* was distributed in various "mountain streams" (my parentheses) of the Otago peninsula. The present day distribution of this species around the Otago peninsula is unknown, and I searched for it unsuccessfully, in Ross Creek. However, I have found both *Austridotea* species in the Catlins area, Southland.

Both species were recorded on Stewart Island in the present survey, although *A. annectans* was rare and was found in only three streams (Fig 4.02) two of which flow into Horseshoe Bay, Nicholl's (1937) original site locality. In contrast, *A. benhami* is widespread (Fig. 4.02) and was collected from most rivers on the north east coast and from streams flowing into Paterson Inlet and Port Pegasus. It also occurred in the top five taxa on three occasions (Table 4.02). Despite extensive searches, *Austridotea* species were not collected from the west coast of Stewart Island.

Like Marshall (1974) I found gravid females in August and small (less than 20 mm long) specimens in August, November and December.

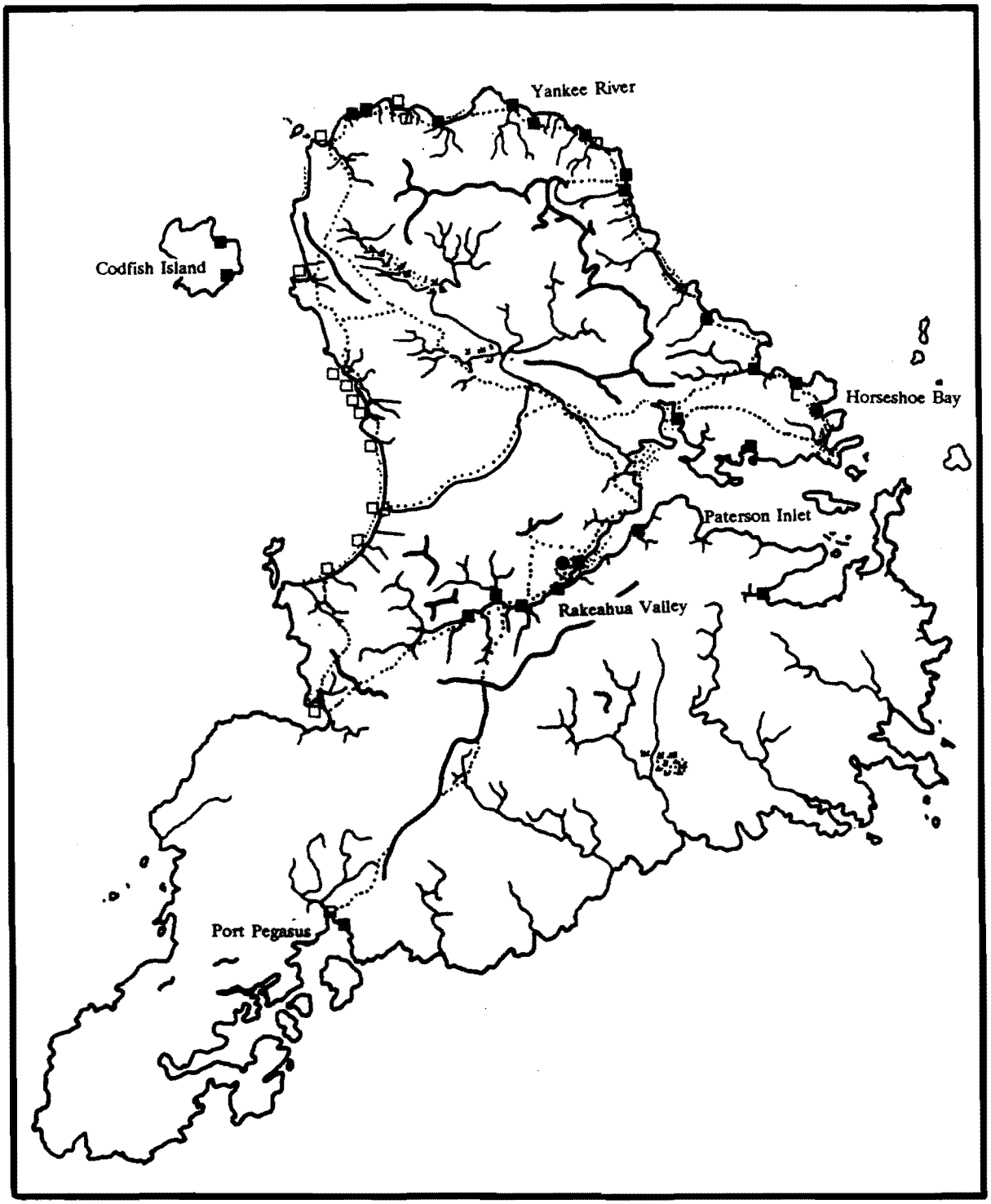


Fig. 4.02. Distribution of *Austridotea benhami* (■) and *A. annectans* (●) on Stewart Island. (□) = searched but *Austridotea* unrecorded.

Both species are commonly associated with woody debris and leafpacks on stony or sandy substrata. Gut analyses revealed that it is omnivorous with woody material present in 90 %, and invertebrates in about 60 % of all isopods examined (Table 4.03). The most common invertebrate prey were leptophlebiids, although simuliids and chironomids were also commonly encountered. Sooty mould fungi were also recorded although it is likely that they were was ingested with wood as only small amounts were present in guts. Mouth parts seem well adapted for feeding on wood and the large toothed mandibles look capable of gouging out chunks of tissue (Plate 4.1A, B, & C). Observations made in the laboratory indicate that *A. benhami* will feed on a variety of live invertebrate prey including late instar Hydrobiosidae, Leptophlebiidae, Siphlonuridae (*Nesameletus*) and large stoneflies. An *Austridotea* would usually wrap itself around a large prey item and hold it with its legs. However, small prey like Chironomidae were usually eaten whole, and swallowed like we would eat spaghetti! There is some evidence of cannibalism, both from gut contents (Table 4.03) and from observations made during salt tolerance tests. In the latter, isopods were eaten although it is not known whether they were taken alive or whether they were already dead.

Distributional evidence suggests that longitudinal / altitudinal distributions of *A. benhami* (and probably *A. annectans*) are related to salinity. In small 1st to 2nd order coastal creeks, *A. benhami* was usually only present in the first few metres above high water mark, and in larger rivers they usually extended no more than 20 or 30 metres into freshwater. However, there were two exceptions to this distributional pattern. In the Rakeahua River, *A. benhami* was collected up to six kilometres from the river mouth (Fig.4.03), whereas in a small stream (1.5 m wide) between Yankee River and Lucky Beach it was present at about 130 m a.s.l., about 700 metres from the coast (Fig. 4.02).

Nicholls (1937) suggested that *A. benhami* was, comparatively speaking, a long established freshwater form, however, most of my distributional records indicate that it is still closely tied to estuarine conditions, and is only nominally a freshwater species. Simple physiological tolerance tests I carried out (Appendix 1) showed that *A. benhami* was tolerant of a wide range of salinities including pure sea water, for periods of up to 10 days. Mortality in these tests was greatest at extremely low and high salinities, i.e., distilled water and pure sea water, which implies they are a brackish water species. The

Table 4.03. Gut contents of 40 *Austridotea benhami* from 8 sites on Stewart Island. Data is expressed as percentage frequency of occurrence, ( ) = actual number of head capsules counted.

INVERTEBRATE 62.5 %		**PLANT MATERIAL 90 %**	
Subcategories:		Subcategories:	
Leptophlebiidae	30.0 %	?Leaf material	7.5 %
Simuliidae	17.5 % (20)	Wood	90 %
Chironomidae	25.0 % (16)		
A. benhami	7.5 %		
Unidentified Arthropod	25.0 %	**FUNGI** (Sooty mould)	32.5%

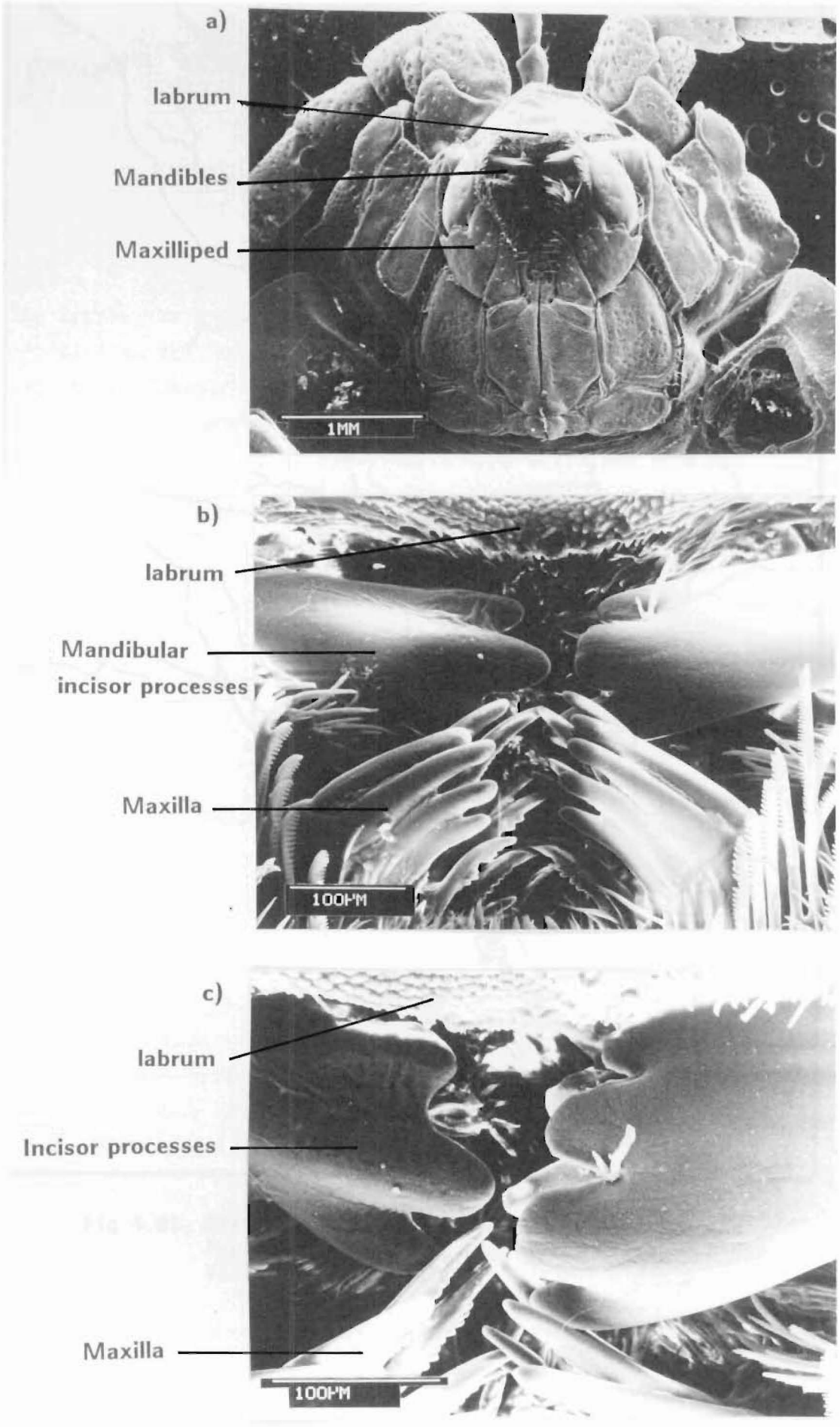
Method of gut analysis.

The exoskeleton was cut along both sides and the dorsal surface removed to expose the alimentary tract. The whole tract was removed and placed on a slide where it was teased apart, mounted in lactophenol-PVA stained in Lignin Pink and dried at 66^{o}C for two days before examination. Slides were viewed at 300X magnification with a Nikon phase contrast microscope. Slides were searched systematically and presence / absence data recorded.

Plate 4.1. (a) An overview of *Austridotea benhami's* mouthparts showing the large, heavily scleritised mandibles, maxillipeds, and labrum.

(b) A close up of the molar like mandibules (incisor processes) and maxilla. Note the comb like teeth of the maxilla which may be used as scrapers. The finer ornate comb like structures (bottom left and right) are the brushes of the maxilliped.

(c) Another close up of the mandibular incisor processes and maxilla, the latter showing a variety of shapes.


a)
labrum
Mandibles
Maxilliped
1MM
b)
labrum
Mandibular
incisor processes
Maxilla
100µM
c)
labrum
Incisor processes
Maxilla
100µM

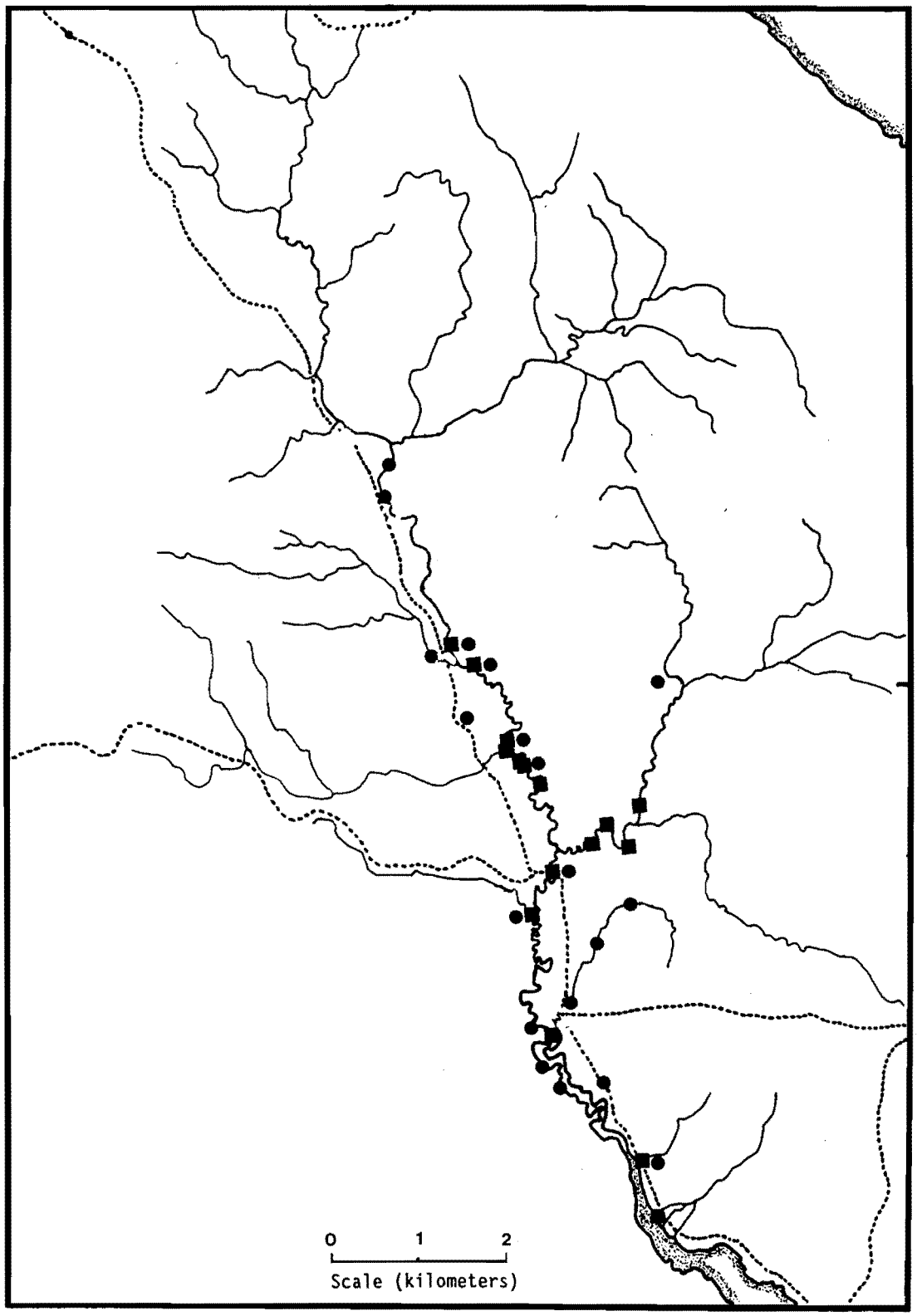


Fig 4.03. Distributions of *Austridotea benhami* (■) and *Paratya curvirostris* (●) in the Rakeahua River Valley, Stewart Island.

exceptional distributions in the Rakeahua River and the small stream near Yankee River indicate varying tolerances exist among geographically distinct populations. This is a phenomenon that is apparently widespread among groups of Isopoda (Green 1968) and has been reported in the family Idoteidae (Croghan and Lockwood 1968) to which *Austridotea* belongs.

Decapoda

The freshwater crayfish *Paranephrops zealandicus* is found only on the eastern side of the South Island, south of North Canterbury, and on Stewart Island (Chapman and Lewis 1976). On Stewart Island, *P. zealandicus* is common and widespread, and probably occurs in all river systems. Largest numbers of individuals were collected from small, stony streams, and an abundant population was also observed in Mount Anglem Tarn.

The only other decapod collected from freshwater was the atyid shrimp *Paratya curvirostris*, although *Palaemon affinis* was recorded in the lower estuarine reaches of the Rakeahua River. *P. curvirostris* was collected from the Rakeahua River, and some small streams flowing into South West Arm of Paterson Inlet. It was also recorded by Cowie *et al.* (1978) from the Freshwater Valley. Shrimps occurred throughout the middle and lower reaches of the Rakeahua River, in both the mainstem and tributaries, including small first order streams (Fig. 4.03).

P. curvirostris appeared to be restricted to shallow gradient streams on Stewart Island, and was never found beyond the transitional zone at the upstream end of the flood plain where the river gradient becomes steeper. Carpenter (1976) suggested that the apparent inability of shrimps to withstand temperatures less than 5^0C may in part restrict their altitudinal distributions. This did not appear to be case on Stewart Island where winter temperature minima in the lower reaches of "Hut Stream", "Stream One" and the main Rakeahua River, were 2, 1.5, and 4.5^0C, respectively (See Chapter 3), yet *Paratya* was abundant. Carpenter (1976) also considered that macrophytes (principally adventives) and bankside vegetation provided important cover and habitat for *Paratya* in lowland Canterbury streams. However, on Stewart Island, adventives are largely unknown (Wilson 1982) and only native water milfoil (*Myriophyllum propinquum*) and pondweed (*Potamogeton suboblongus*) are locally common in the Rakeahua Valley. Instead, woody debris, dead manuka bushes, bankside vegetation (flaxes and grass) and undercut banks provided important

habitats for shrimps in the Rakeahua Valley and elsewhere. Carpenter (1976) suggested that water course management, in particular weed clearing and channel deepening, had made important contributions to the decline of shrimp populations and had resulted in fragmentation of the species' geographical range. My work suggests that removal or loss of wood debris has also been important in this respect.

Amphipoda

Seven amphipod OTUs were identified from Stewart Island and although all can be abundant, most were restricted to a few localities or habitat types. Exceptions were *Chiltonia rivertonensis*, *Paraleptamphopus subterraneus* and to lesser extent *Paracalliope* spl., all of which were widespread and present at 89, 40 and 22 % of sites, respectively. *C. rivertonensis* was the most abundant invertebrate at 42 % of sites, and was particularly common in mossy habitats where numerically it could account for over 60 % of the fauna (see Part II of this chapter).

Mollusca

Potamopyrgus antipodarum is widespread (40 % of sites) and was a member of the top five taxa on 11 occasions (Table 4.02), whereas *Sphaerium noveazealandiae* was only collected from three sites in the lower Rakeahua Valley. *Potamopyrgus estuarinus* was positively identified at one lower river site but is probably more widespread.

No introduced molluscs such as *Physa acuta* or *Lymnaea* species have been collected from Stewart Island.

Tricladida

Flatworms were collected from 12 sites and were at times locally common. Nurse (1950) recorded *Neppia montana* from the east coast of Stewart Island, and all specimens appeared to belong to this species.

Neppia montana has broad habitat requirements on the mainland (Cowie and Winterbourn 1979), and on Stewart Island it was collected from small, slow flowing first order streams and from bouldery gorge areas with turbulent flows.

COMPARISONS WITH MAINLAND FAUNAS

The dominance of aquatic insects (81 % of 113 taxa) in benthic invertebrate faunal lists is consistent with results of extensive

mainland surveys of streams and rivers (Rounick and Winterbourn 1982, (87 %), Winterbourn and Collier 1987 (82 %), Quinn and Hickey (ms) (82 %)).

However, a number of important mainland families and genera are notable for their absence or relative rarity on Stewart Island. In particular, the families Notonemouridae and Conoesucidae are represented by single species (*Cristaperla fimbria*, and a *Pycnocentria* species, respectively), and cased caddis in general are poorly represented. What cased caddis are present, are rarely abundant.

Furthermore, of Winterbourn *et al.*'s (1981) nucleus of common genera, the dobsonfly *Archichauliodes* and the caddisfly *Olinga* are almost certainly absent. Adults of the former are shortlived (six to ten days), slow and clumsy fliers with heavy bodies and awkward wings (Hamilton 1940). Therefore it is unlikely that they would be able to colonise Stewart Island by crossing Foveaux Strait against the prevailing south westerly winds.

Relatively few leptophlebiid species were encountered (10) particularly in comparison with the 28 recorded by Towns (1987) from Great Barrier Island. In part this may relate to difficulties in recognising species, but more probably it reflects a general paucity of Leptophlebiidae in the south of New Zealand (Cowie 1980, Graesser 1988, Collier 1988). Towns (1987) suggested that the relatively few leptophlebiid taxa found in the south may in part reflect a tendency to sample stony substrates where not all taxa occur. However, I collected from a wide range of substrate types and flow conditions and still obtained few species.

Some New Zealand mayflies tolerate an extremely narrow range of environmental conditions (Towns 1987), hence extinctions may have occurred during the Otira galaciation when forest cover appears to have been lost from Stewart Island (Wells and Marks 1966). The short lived adult life stage (2 to 3 days), and its limited dispersal ability (Edmunds 1972) also probably hindered colonisation following separation of Stewart Island from the mainland at the end of the Otira glaciation. Another possibility is that the Leptophlebiidae are a warm water group which has speciated less in the colder south (M.J. Winterbourn pers. comm.)

Although notonemourids are widely distributed on the mainland today (Winterbourn *et al.* 1981), this may be a recent phenomenon. *Cristaperla fimbria* is the only notonemourid recorded from Stewart Island and from

Southland (J. Quinn and G. Ryder pers. comm.), suggesting either that colonisation from the north has been slow, or that like the Leptophlebiidae, there is a southern decrease in the diversity and distribution of this family that may be associated with climate.

In contrast to the above, a number of taxa that have restricted or poorly known distributions on the mainland are present on Stewart Island. They include *Mauiulus luma* (Leptophlebiidae), *Neocurupira tonnoiri* (Blephariceridae), *Mischoderus* spp. (Tanyderidae), caddisflies of the Ecnomidae/Pschomiidae complex and the *Pseudoeconesus* spp. (Oeconesidae), and *Austridotea* (Isopoda). Their relative commonness on Stewart Island may reflect the continuing presence of suitable habitat there in contrast to that available on the mainland.

However, *Austridotea* species may be more widespread on the mainland than current knowledge suggests, as its relatively specialised habitat (the estuarine/freshwater ecotone) appears to have been overlooked or poorly sampled by most New Zealand limnologists. Nevertheless, lowland areas inhabited by *Austridotea* have undergone great changes and habitat modifications following human colonisation (Winterbourn 1987) and these can be expected to have adversely affected this group. Certainly, Marshall (1974) suggested that *A. annectans* was intolerant of fine sediment or organic enrichment of running waters, and he believed that these factors contributed to its restricted distribution in the Leeston Drain.

One of the most distinctive features of Stewart Island's invertebrate fauna are the Amphipoda, particularly *C. rivertonensis*, *P. subteranneus* and to a lesser extent *Paracalliope* sp.1. *Chiltonia* is rarely encountered on the mainland, whereas species of *Paraleptamphopus* are common in springs, spring brooks and streams of low pH (Chapman and Lewis 1976, Collier 1988, Collier *et al.* 1989), and *Paracalliope* is widespread and often abudant in many lowland rivers. It is often associated with marginal vegetation or aquatic macrophytes (Winterbourn 1981) although Marshall (1974) and Towns (1979) both collected it from gravel stream beds. Available evidence suggests that Amphipoda are a characteristic component of many "stable" mid-lowland stream faunas in New Zealand and therefore it follows that they should be an important component of Stewart Island's freshwater fauna. The ability of some amphipod species to colonise upland, forested streams on Stewart Island may be related to

the high bed stability and thick bryophyte cover that is frequently present.

PART II

COMMUNITY COMPOSITION AND THE INFLUENCE OF ENVIRONMENTAL VARIABLES

INTRODUCTION

Recent interest in the effects of anthropogenic acidification in Northern Hemisphere streams has provided the impetus for research into the freshwater ecology of naturally acidic, brown water streams in New Zealand. Initial work on the west coast of the South Island (Winterbourn and Collier 1987, Collier and Winterbourn 1987, Winterbourn *et al.* 1988) indicated selected chemical parameters (including pH) were not important in determining species richness and distributions of benthic invertebrates in streams above about pH 4.5. Rather, stream channel stability and the availability of suitable colonisers appeared to be important determinants of the composition of benthic assemblages at a particular locality. More recently, however, Collier *et al.* (1989) found that lower gradient (and presumably relatively more stable) acidic streams (pH mostly < 5.0) draining modified wetland catchments on the west coast, supported fewer invertebrate taxa than sites that consistently had pH > 4.5 and which drained native forest. They concluded that invertebrate colonisation appeared to be limited by the extreme acidity of brown water streams on pakahi wetlands.

Stewart Island streams are chemically similar to many streams on the west coast of the South Island, at least in terms of acidity (pH 4.5-7.4), DOC concentrations, and alkalinity, although many conductivity values I obtained were considerably higher than those reported by Winterbourn and Collier (1987), and concentrations of salts (Na^+ and Cl^-) indicate a coastal, marine influence. They also differ in that they do not appear to be as physically unstable (sensu Pfankuch 1975) and contain greater amounts of moss than many westland streams at similar altitudes.

In this chapter, the macro-invertebrate communities of a broad range of Stewart Island streams are described and the relationship between community composition and selected environmental variables is examined.

METHODS

Forty five stream sites on Stewart Island (Fig. 4.04) were sampled between December 1988 and November 1989, although most sites were sampled in January. Sites were sampled with a 0.25 mm mesh, kick net, held down stream of stony substrates or debris which were disturbed by foot or turned over and scrubbed by hand, for about three minutes. All samples were stored in 4 to 10 % formalin and sorted later in the laboratory. Samples were washed over a 2 mm mesh sieve and collected on a 0.42 mm mesh sieve. Material retained by the coarse sieve (2 mm mesh) was sorted by eye, whereas smaller animals (0.42 mm mesh) were separated from debris by floatation using a $CaCl_2$ solution (specific gravity 1.12), and sorted under a binocular microscope in a Bogorov counting tray (Gannon 1971). Fine debris that sank in the $CaCl_2$ treatment was subsampled in a quadripartite sample splitter and because of its large quantity only one subsample was sorted.

Invertebrates were identified to operational taxonomic units (OTUs)which in most cases were species or probable (but unidentifiable) species (see Part I). Larvae of the mayfly *Deleatidium* and the black fly *Austrosimulium* were not identified to species.

Several environmental variables were measured at most sites. Water samples were collected, and pH, conductivity, DOC concentration, and alkalinity were measured as described in Chapter 3. Two measures of stability were used; total Pfankuch scores, and stream bed scores (the stream bottom component of the index). Temperature, channel width, and maximum surface current velocity were measured, the latter by the velocity head rod technique (Drost 1963).

Percentage moss cover, dominant surface substrate type and riparian vegetation at each site were noted on survey forms (see Chapter 3, Fig. 3.3). For analysis, five vegetation types were recognised; open (open country grasslands or dune systems), coastal scrub, manuka scrub, podocarp forest, and alpine.

Dominant substrata were assigned numerical values that ranged from sand (assigned a value of 0) to gravel (25), cobbles (50), boulders (75),

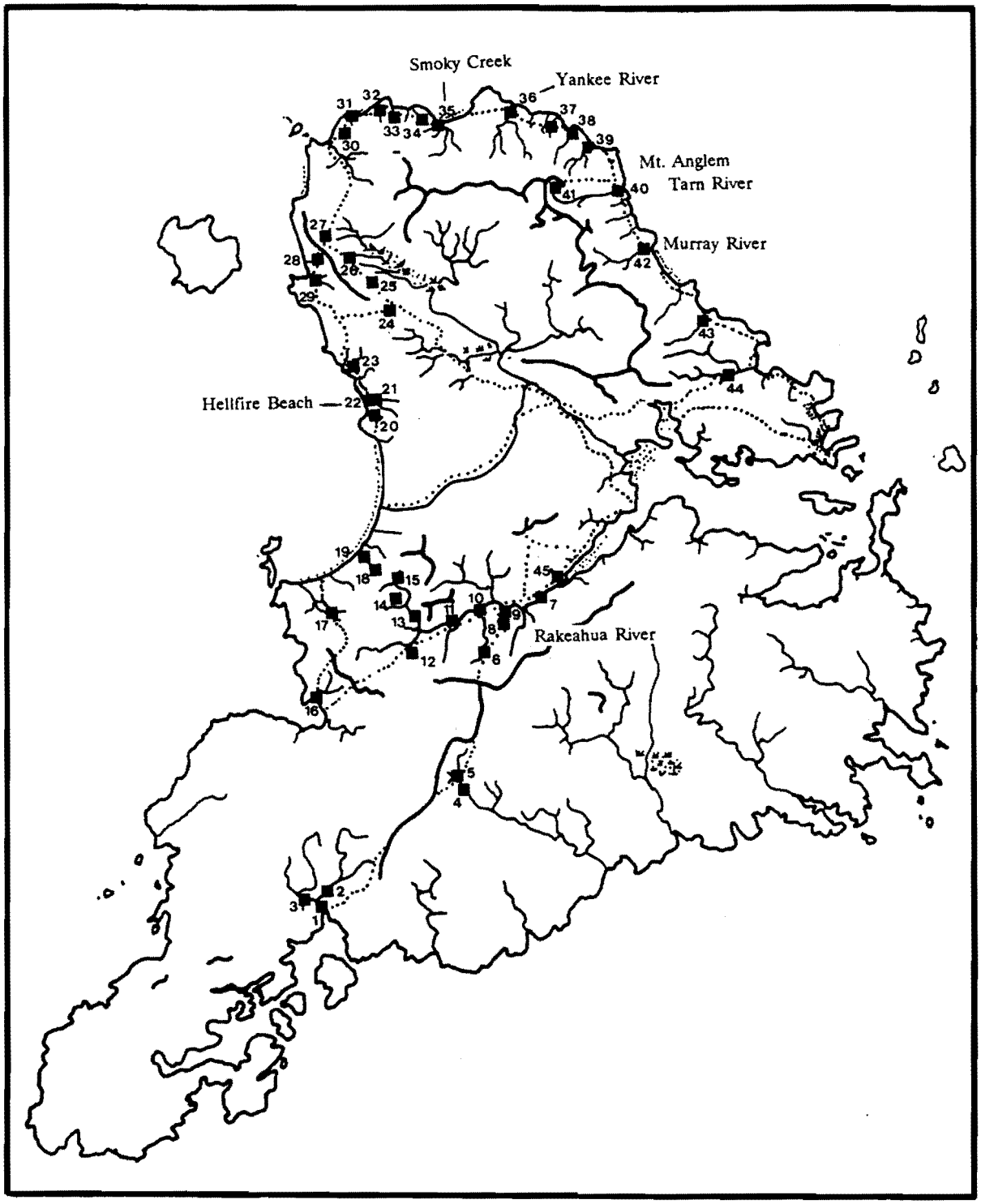


Fig. 4.04. Stewart Island invertebrate survey sites sampled between December 1988 and November 1989.

and bedrock (100). Depending on substrata present, sites were given a value on this scale.

For analysis, streams were placed in seven site locality groups; Southern (Sites 1 to 5), Rakeahua Valley (Sites 6 to 15), west coast (Sites 16 to 23 and 28,29), western central (Sites 24 to 27), north west coast (Sites 30 to 35), north east group (Sites 36,37,38,41), and east coast (Sites 39 to 44, Fig. 4.04).

Temperature was not included in the analysis as sites were sampled in a number of months and differences among them would be affected by weather and seasonal factors.

Sites were classified using relative abundance data for 100 OTUs. Cluster analysis was used to classify sites into coarse groupings for descriptive purposes. Similarity co-efficients were calculated for each site using the Bray Curtis index (BC) and then clustered using the hierarchical group average linkage procedure (PC-ORD, multivariate statistics package, McCune 1987).

The Bray Curtis index has the formula

$$BC = 2W/(A + B)$$

where BC = Bray Curtis coefficient of similarity, and A and B are the sums of species values for samples A and B. W is the sum of the lesser species common to both samples (Bray and Curtis 1957).

Ordination of sites was carried out using detrended correspondence analysis (DECORANA, Hill 1979) with down weighting of rare species in proportion to their frequency. This was done so that individual samples containing rare species would not distort the analysis (Wright *et al.* 1984). DECORANA was also used to confirm cluster groupings as recommended by Stark (1985).

DECORANA axes and taxonomic richness were correlated with 12 environmental variables (STATISTIX, NH Analytical Software). Stepwise multiple regression analysis was then used to assess the importance of these variables in explaining DECORANA axes and taxonomic richness patterns, as many were intercorrelated.

RESULTS

Thirty four OTUs occurred in the list of top five taxa for each site (Table 4.02) and a common core of 11 taxa occurred at over 50 % of all sites. The latter included *Chiltonia rivertonensis*, Chironomidae,

Oligochaeta, *Deleatidium*, *Zelandobius confusus*, *Zelandoperla (agnestis and/or fenestrata)*, *Austroperla cyrene*, Simuliidae, *Hydrobiosella stenocerca*, Scirtidae and immature Hydrobiosidae. A further three taxa (*Oxyethira albiceps*, *Potamopyrgus antipodarum*, and *Paraleptamphopus subterraneus*) occurred at just under 50 % of the sites, and were in the top five list at over 20% of them.

Faunal assemblages

Clusters were weakly differentiated (Fig. 4.05) and rather than being defined by unique groups of taxa, they represent groupings based on different relative abundances of a few common taxa.

Five main groups consisting of 4-12 sites, and 5 "outliers" (sites separated very early in the analysis) could be distinguished at the fifth and sixth levels of separation.

DECORANA confirmed that the distinctiveness of these groups was weak, except for group 1 (Fig. 4.06).

Two further groups were created for sites where *A. benhami* was common (sites marked A on Fig. 4.05) and where moss cover was greater than 80 % of substrate (M on Fig. 4.05).

Group 1 was characterised by eleven OTUs which are mainly "common core taxa" on Stewart Island, and also the rarer *P. subterraneus* (Fig. 4.07). Numerically, the fauna was dominated by the amphipod, *C. rivertonensis* (average relative abundance, 66 %). Chironomidae (10.6 %) and Oligochaeta (5.2 %) were the next most abundant taxa. Physicochemically, these sites were not distinctive (Table 4.04), but most were relatively stable streams (Pfankuch scores 42-83) usually with greater than 50 % moss cover. Exceptions were three sites with sandy beds and abundant woody debris. A large amount of this stable woody debris was covered by moss amongst which many of the characteristic group 1 taxa lived.

Group 2 had the most diverse fauna, which comprised 17 OTUs including six species that were not common core taxa (Fig.4.08). Although *C. rivertonensis* was again the numerically dominant invertebrate, it only accounted for an average of 19.1 % of the fauna, and Chironomidae (11.8 %), *Deleatidium* (10.3 %), *Coloburiscus* (8.8 %), and Oligochaeta (7.2 %) were almost as common. Of interest was the high abundance of *A. cyrene* (4.4 %) and the presence of two other opportunistic shredders, *Z.*

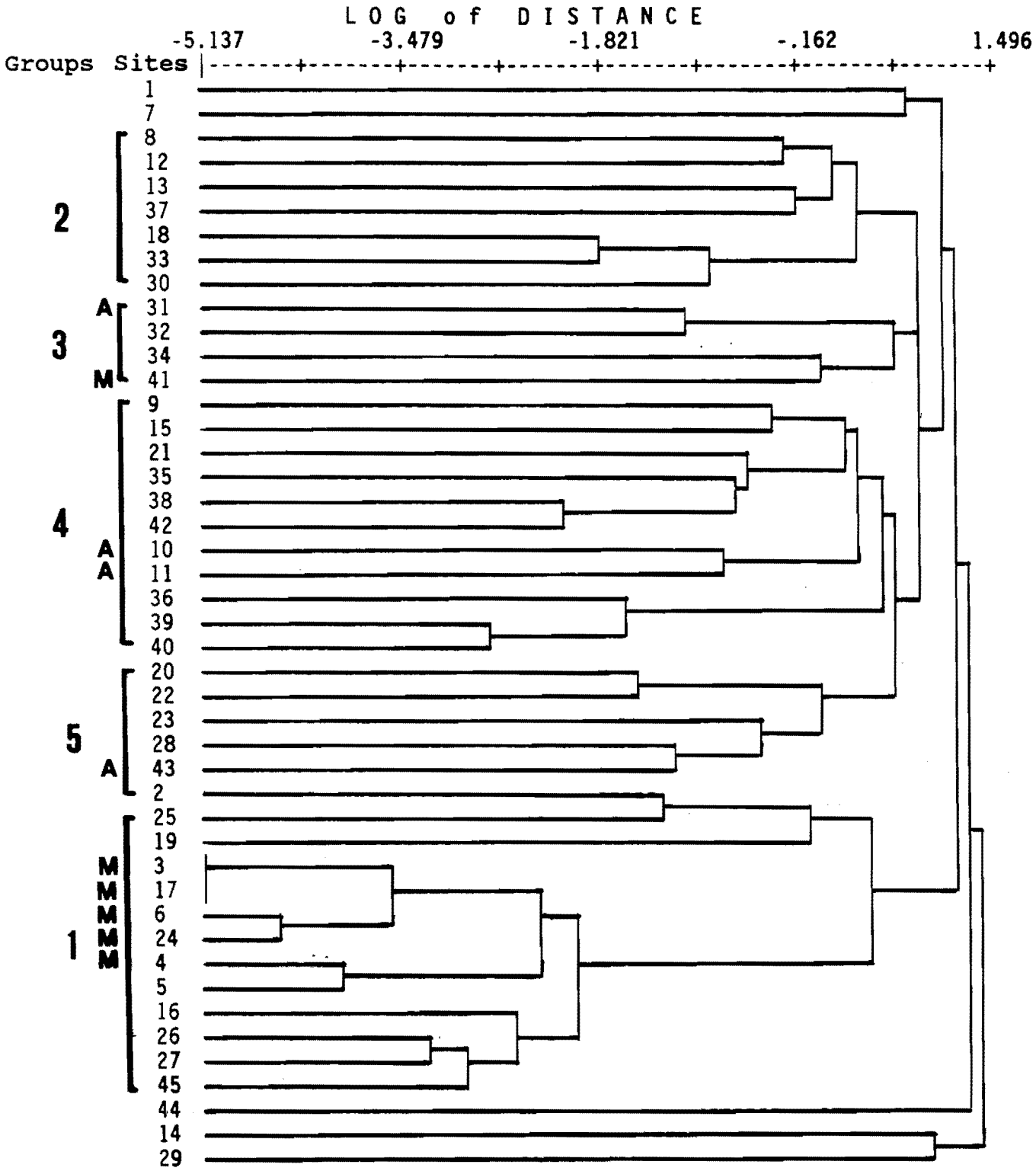


Fig. 4.05. Site clusters obtained using the Bray Curtis coefficient calculated from invertebrate relative abundance data. Site cluster groups 1, 2, 3, 4, and 5, and the *Austridotea* (A) and moss (M) groups are shown.

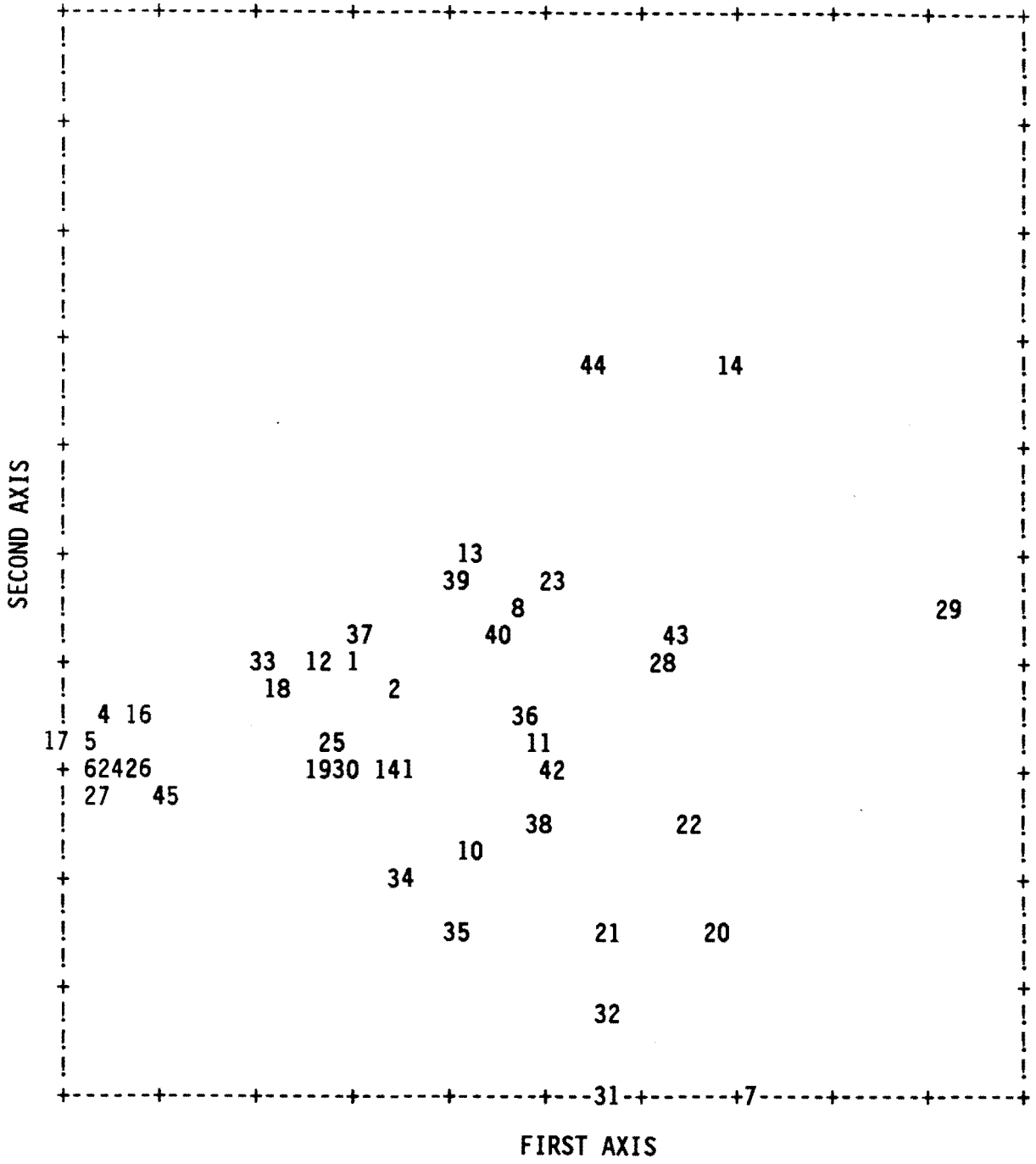


Fig. 4.06. Stewart Island invertebrate assemblages (sites) plotted on DECORANA axes 1 and 2, based on relative abundance data collected between December 1988 and November 1989.

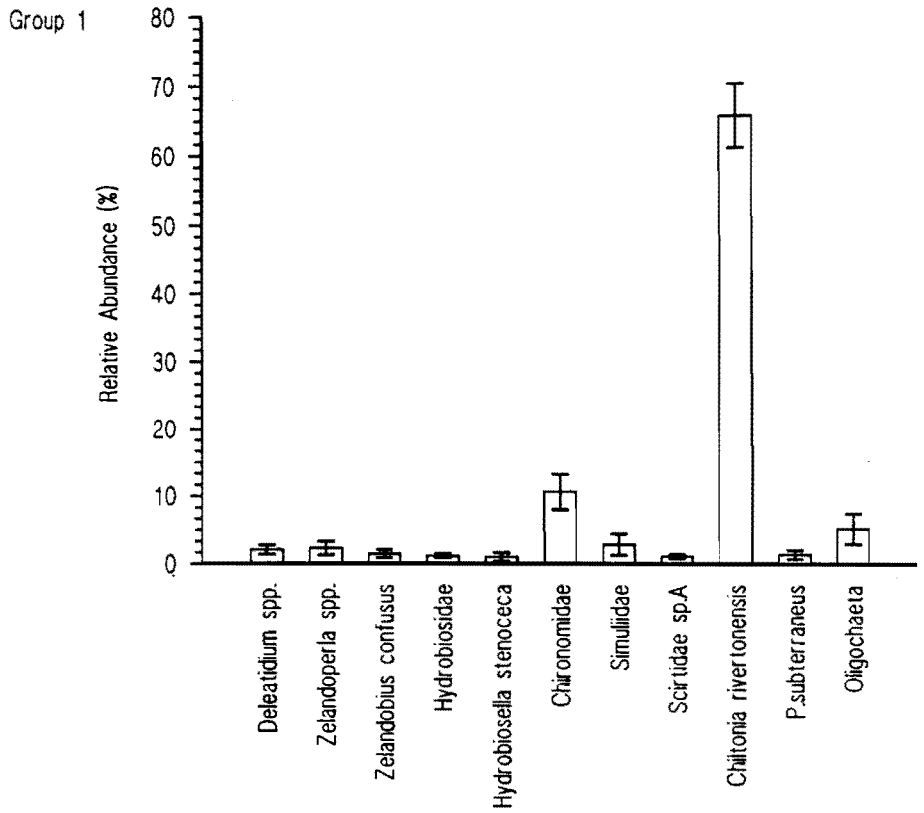


Fig. 4.07. Average relative abundance of taxa making up more than 1 % (RA) and occurring at more than 50 % of sites in Cluster group 1 (or any taxa occuring at all sites).

Group:	1	2	3	4	5	Austridotea
pH.	4.6-7.1 (5.9)	6.3-7.0 (6.7)	6.2-6.8 (6.4)	6.3-7.3 (6.8)	5.4-7.1 (6.2)	6.2-7.1 (6.7)
DOC (gm^{-3})	6.5-19.8 (12.1)	5.2-11.0 (8.7)	5.0-15.2 (9.5)	6.6-13.9 (8.9)	8.2-20.8 (13.0)	6.6-15.9 (9.3)
CONDUCTIVITY (mSm^{-1})	6.4-43.2 (22.7)	17.9-62.6 (31.0)	5.4-51.9 (32.7)	10.7-58.3 (20.1)	12.0-70.2 (45.0)	12.0-51.9 (26.1)
STABILITY (TOTAL)	42-83 (61)	42-77 (62.2)	37-81 (62.3)	68-139 (94.9)	58-113 (76.7)	70-113 (92.1)
STABILITY (stream bed)	15-41 (24.3)	15-36 (23.1)	15-45 (27)	26-60 (36)	17-49 (26.9)	26-49 (33.5)
MOSS COVER (%)	40-100 (69.8)	0-55 (29.2)	10-98 (42)	0-30 (7.2)	0-50 (23)	5-10 (7.5)
CURRENT (ms^{-1})	40-153 (77)	25-70 (43.2)	28-50.5 (40.1)	10-85.2 (51.1)	28-71.4 (48.7)	10-71 (50.5)
WIDTH (m)	0.5-5.0 (2.1)	0.5-7.0 (1.9)	0.8-2.5 (1.6)	2.0-6.0 (4.0)	1.0-5.0 (3.3)	2-7 (5)
Total no. taxa:	12-23 (26)	26-41 (32)	26-40 (32)	17-43 (27)	17-30 (24)	24-36 (28)

Table 4.04. Physicochemical characteristics of the five main groups of streams and the *A. benhami* group sites, distinguished in Fig. 4.05. Percentage moss cover and numbers of taxa (OTUs) found are also shown.

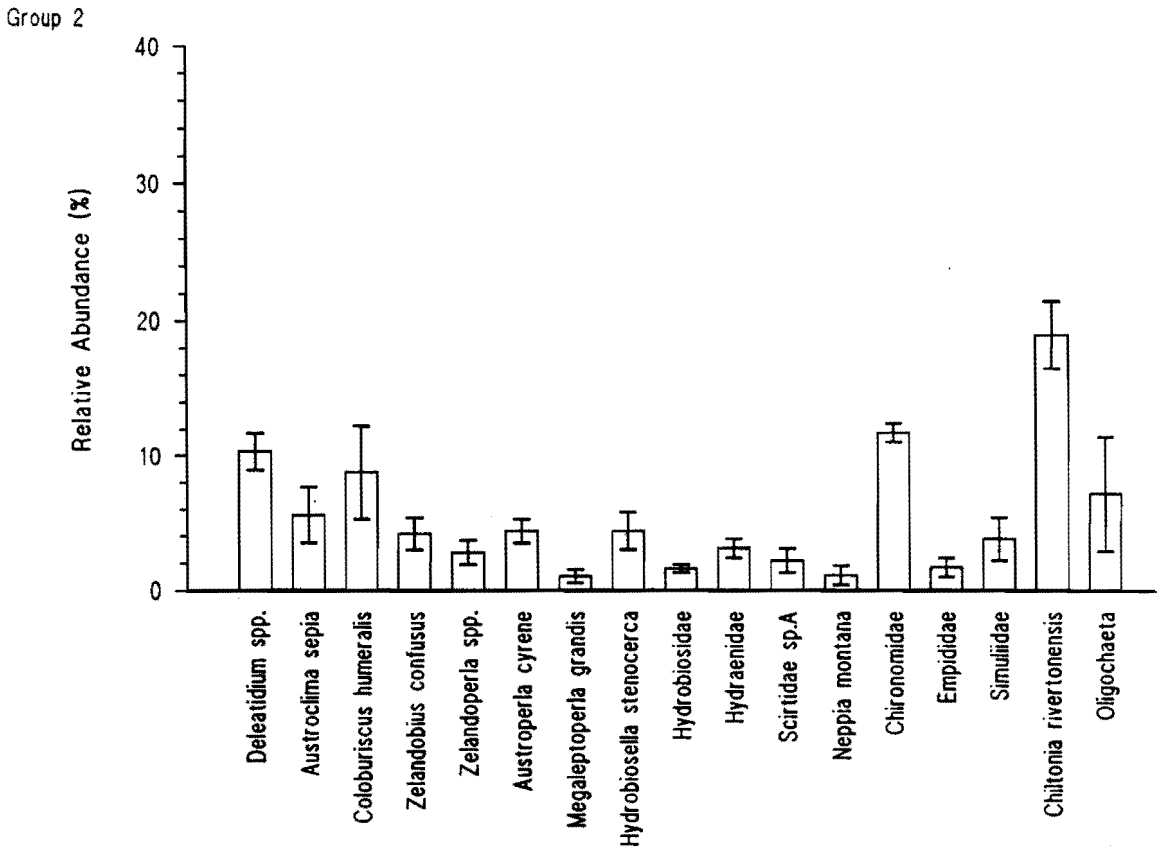


Fig. 4.08. Average relative abundance of taxa making up more than 1 % (RA) and occurring at more than 50 % of sites in Cluster group 2 (and any taxa occuring at all sites).

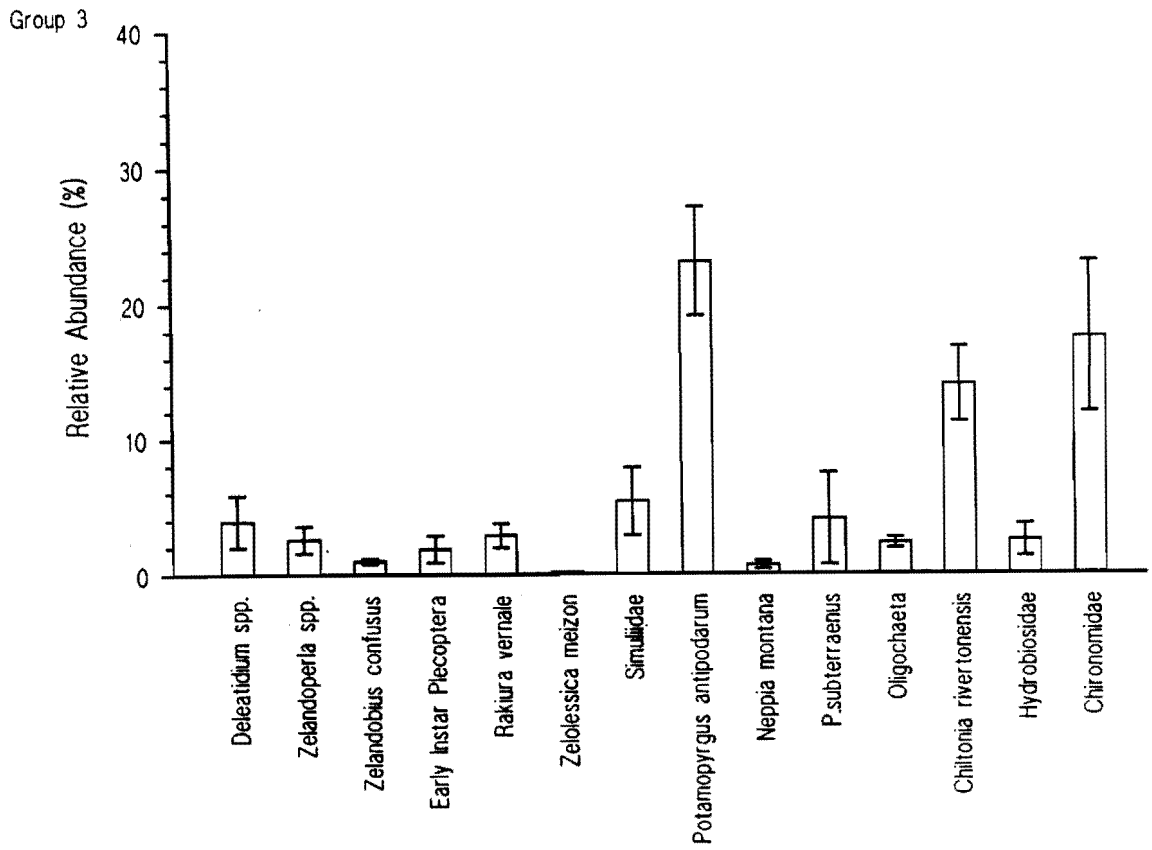


Fig. 4.09. Average relative abundance of taxa making up more than 1 % (RA) and occurring at more than 50 % of sites in Cluster group 3 (and any taxa occuring at all sites).

agnestis, and Hydraenidae (2.8 and 3.1 %, respectively). Three filter feeders were also common (*C. humeralis*, *H. stenocerca*, and Simuliidae).

With the exception of Site 12, all sites in Group 2 were small streams (0.5 to 1.5 m wide) with 'good' stream bed stability (Pfankuch 1975) (Table 4.04), and closed canopies. In contrast, Site 12 was a large (7 m wide), stable river with an open canopy in the Rakeahua gorge. Chemically, these sites were moderately acidic to circumneutral waters, with low DOC concentrations and high conductivity.

Group 3 comprised only four sites, and was unique because of the dominance of *Potamopyrgus antipodarum* (23.2 %), and the presence of two cased caddis, *Rakiura vernale* and *Zelolessica meizon*. Chironomidae (17.6 %) and *C. rivertonensis* (14.1 %) were the other numerically important components of the fauna (Fig. 4.09). These sites were in close proximity to each other in northern Stewart Island (Fig 4.01) and were on small (0.8 to 2.5 m wide) streams of diverse physicochemical character (Table 4.04).

Group 4 was similar to Group 2 except that it contained fewer species (*M. grandis*, *A. sepia*, Scirtidae spA. and *Neppia montana* were absent), and an elmid, *Hydora* sp. was present. Shredders and filter feeders were rarer than in Group 2 and the dominant taxa were Chironomidae (45 %) and *Deleatidium* (15.5 %, Fig. 4.10). *C. rivertonensis* and Oligochaeta were less important than in Groups 1, 2, and 3.

Streams making up Group 4 were mainly in the Rakeahua Valley (Sites 9, 10, 11, 15) and on the north east coast between Murray River and Smoky Beach (Sites 35, 36, 38, 39, 40, 42, Fig. 4.04). Site 21 was at Hellfire beach (Fig. 4.04) and therefore was further west than the other sites. Most of the sites were clear, circumneutral waters, with 'fair' to 'poor' stream stability ratings (Table 4.04). Stream beds were either sandy, armoured, or composed of loose gravels, and thus had lower substrate heterogeneity and fewer spatial refuges from floods than most other sites sampled on Stewart Island.

The fauna of Group 5 was again dominated by common core taxa, but Oligochaeta (31 %) and Chironomidae (28.6 %) were most abundant, and *C. rivertonensis* (2.5 %) was relatively rare. *Deleatidium* (8.1 %) was also relatively abundant (Fig. 4.11). Of interest were the presence of the algal piercer, *Oxyethira albiceps*, the hydropsychid, *Aoteapsyche rarurarau*

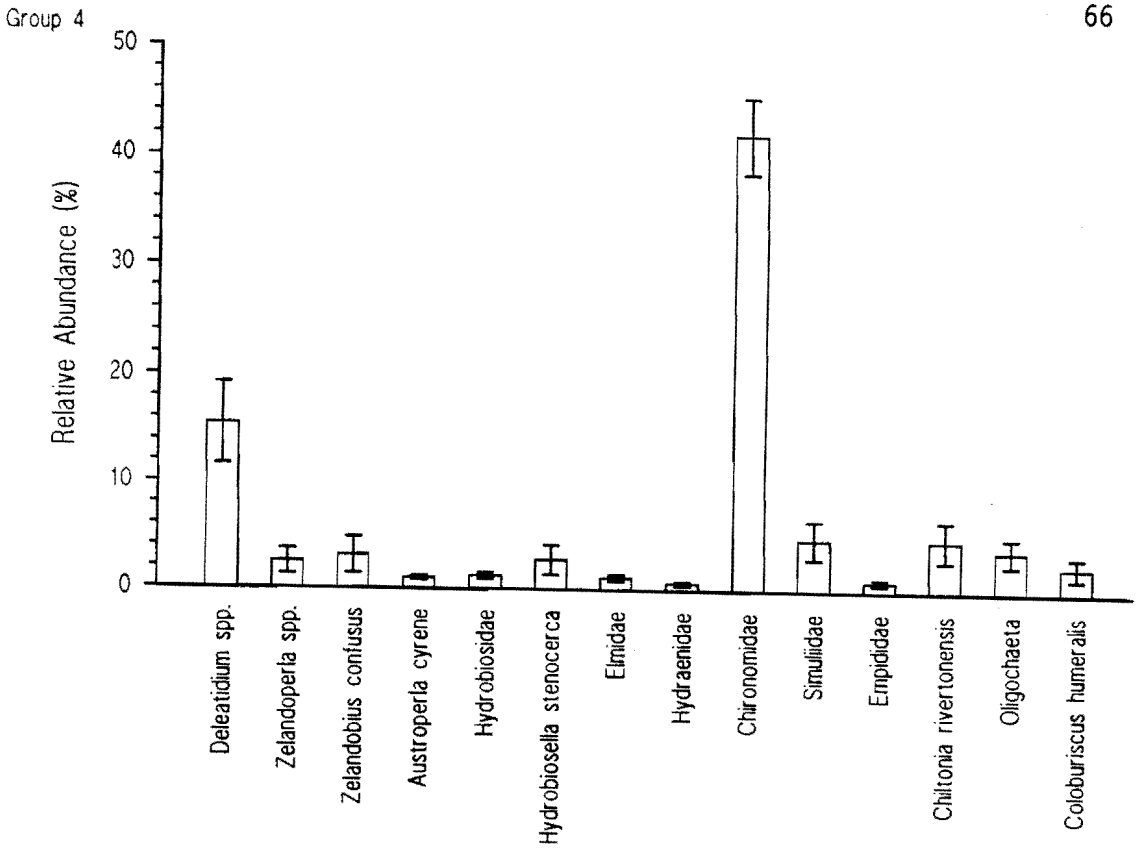


Fig. 4.10 Average relative abundance of taxa making up more than 1 % (RA) and occurring at more than 50 % of sites in Cluster group 4 (and any taxa occuring at all sites).

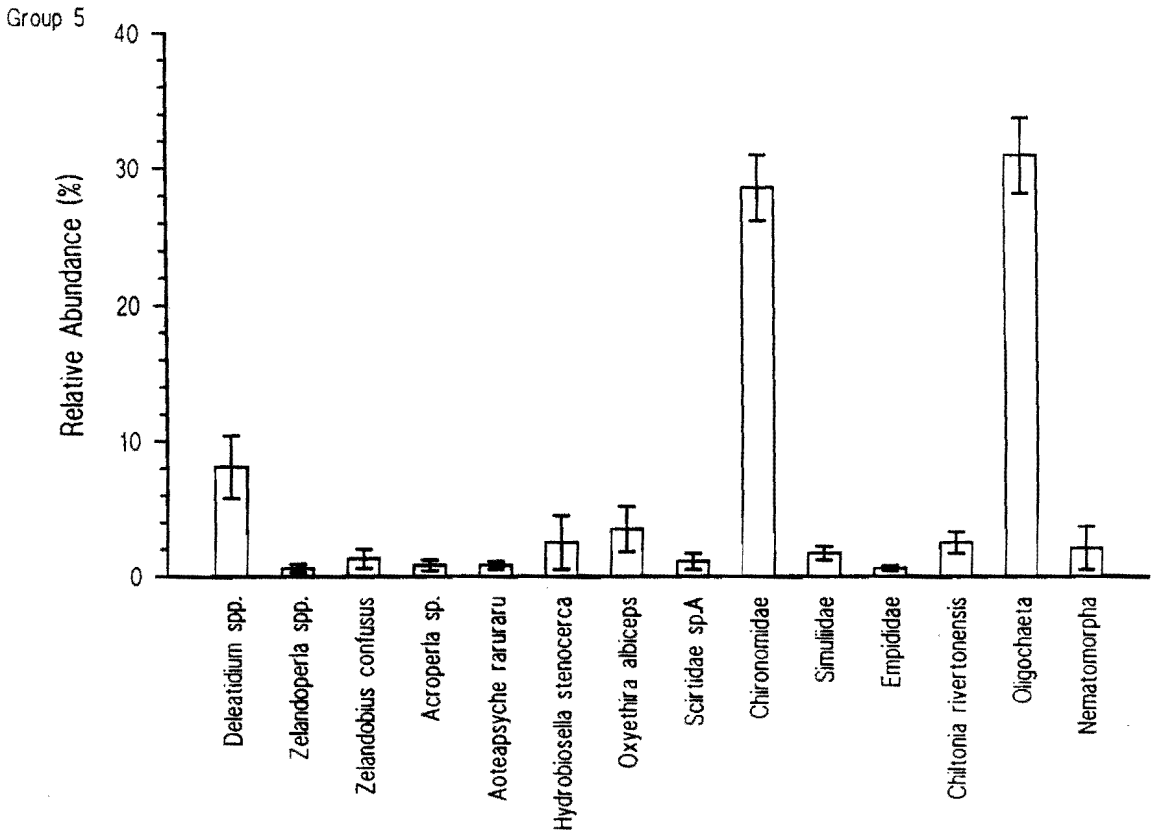


Fig. 4.11. Average relative abundance of taxa making up more than 1 % (RA) and occurring at more than 50 % of sites in Cluster group 5 (and any taxa occuring at all sites).

and an undescribed *Acroperla* species, all of which were most abundant in this group. Sites were all coastal and incorporated a wide range of physicochemical conditions (Table 4.04). They had open canopies and conspicuous algal films or filamentous algal growths were present at the time of sampling.

The *Austridotea* sites were the four (A on Fig. 4.05) where *A. benhami* made up more than 3.0 % of the relative abundance of invertebrates. Numerous species were associated with *A. benhami* and common taxa (i.e., OTUs making up more than 1 % of numbers) made up about 70 % of the fauna. Dominant OTUs were Chironomidae, Oligochaeta, *Deleatidium* and Simuliidae, and to a lesser extent *Zelandobius confusus* which was on average only slightly more abundant than *A. benhami* (Fig. 4.12). Physicochemically, these sites were characterised by moderate to high conductivity, slightly acidic to circumneutral pH, low to moderate DOC concentrations and 'fair' stream bed stability (Table 4.04).

The moss fauna ("M" sites, Fig. 4.05) was only slightly different from that at Group 1 sites, although Chironomidae and *Zelandoperla* spp. were more abundant on average, whereas *C. rivertonensis* was less common (Fig. 4.13).

Relationships with environmental variables

Almost half the variance explained by the three DECORANA axes was explained by Axis 1 (49 %), whereas axis 2 and axis 3 accounted for 28 and 22 %, respectively.

Axis one was significantly correlated with percentage moss cover, total stability, conductivity, substrate type, and maximum surface current velocity (Table 4.05). However, these variables were intercorrelated (see Chapter 2) and only percentage moss cover, and conductivity were retained by stepwise multiple regression analysis. This yielded a regression equation (Table 4.06) that had r^2 values of 0.59 (combined) or 0.52, (percentage moss cover alone, $P < 0.001$).

The abundances of 42 taxa were found to be significantly correlated with DECORANA axes (Table 4.07). Species positively correlated with axis 1 were those common on non-mossy substrates in low conductivity streams. They include Chironomidae, Oligochaeta, *Potamopyrgus antipodarum*, and *Helicopsyche* spp.. In contrast, the abundance of *C. rivertonensis*,

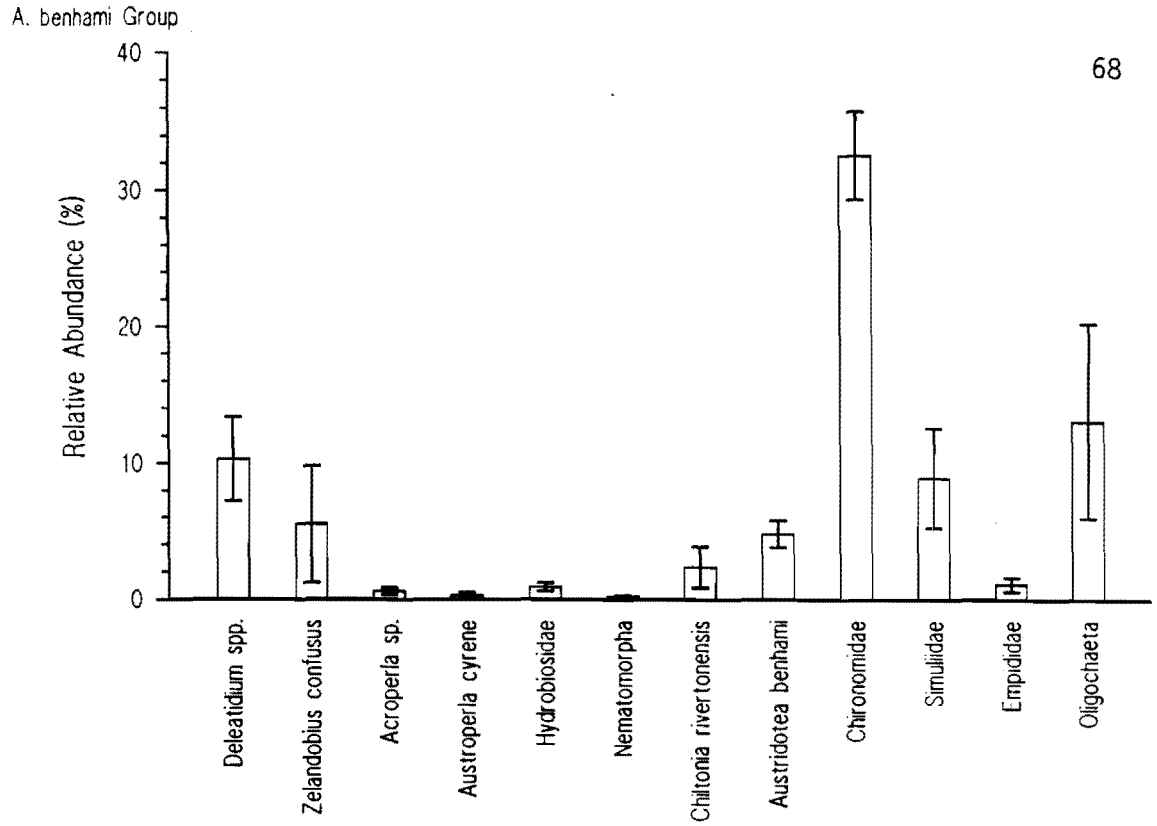


Fig. 4.12. Average relative abundance of taxa making up more than 1 % (RA), and occurring at more than 50 % of all sites where *A. benhami* was greater than 3.0 % (RA) (and any taxa occuring at all sites).

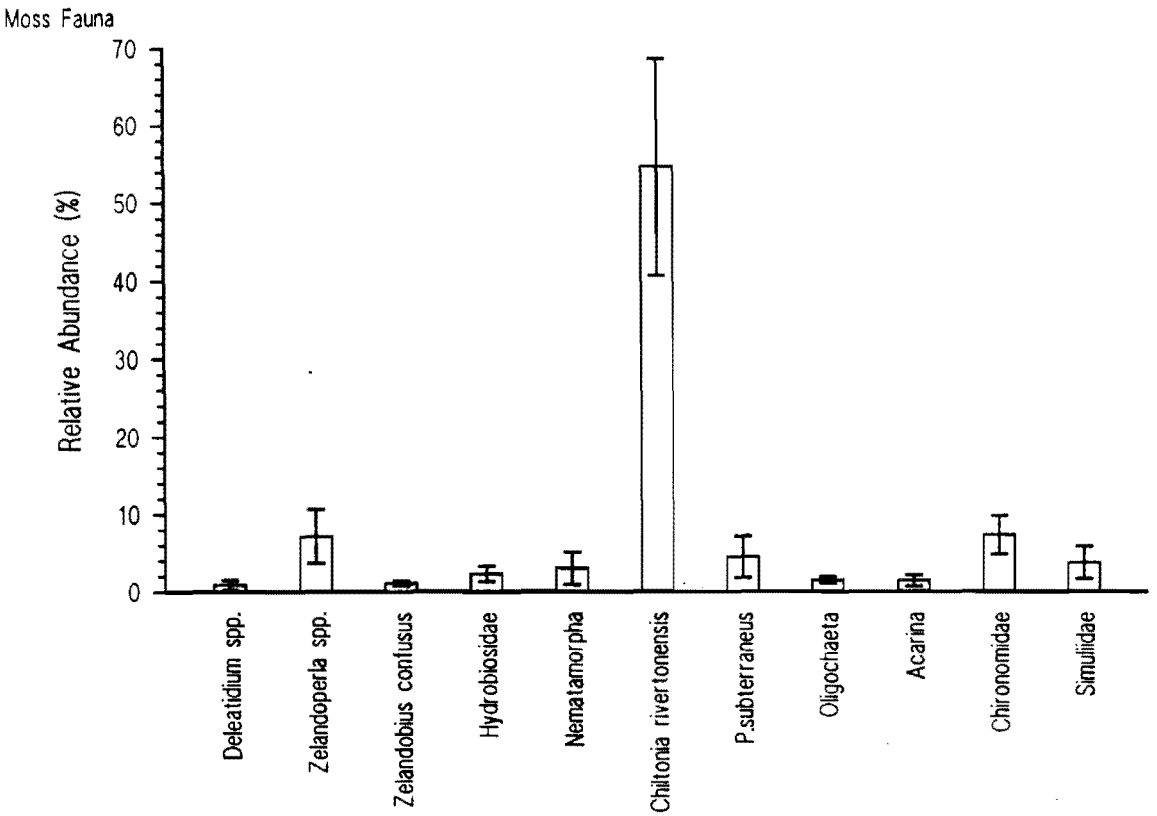


Fig. 4.13. Average relative abundance of taxa making up more than 1 % (RA) and occurring at more than 50 % of all sites, where moss cover was greater than 80 %.

Table 4.05 Correlation (r) between various descriptive stream parameters and DECORANA axes 1, 2, and 3, and total numbers of OTUs (relative abundance data, * P < 0.1 ** P < 0.05 *** P < 0.01).

	Axis 1	Axis 2	Axis 3	Total OTUs
			***	*
pH	0.23	-0.03	0.46	0.32
			***	
DOC concentration	0.10	-0.10	-0.50	-0.25
	***	*		
Conductivity	0.42	-0.30	-0.20	-0.01
			**	
Alkalinity	0.21	-0.15	0.35	0.06
	***		*	
Percentage moss cover	0.69	-0.06	-0.31	-0.15
	**			
Pfanckuch stability	0.41	0.11	0.22	0.19
Stream bed stability	0.27	0.13	0.26	0.15
			**	
Width	0.21	0.22	0.38	0.01
	**			
Substrate	-0.33	0.07	0.10	-0.06
		**	**	***
Vegetation type	-0.22	-0.38	-0.36	-0.49
	*	**		
Current	-0.31	0.35	0.27	-0.02
		***	**	***
Location	-0.1	-0.43	-0.35	-0.48

Table 4.06 Multiple regression equation (with r^2) derived from environmental variables to describe DECORANA axes and total numbers of OTUs (relative abundance data).

Axis	Regression equation	r^2
Axis 1	141.8 + 1.26 (conductivity) - 1.56 (% moss cover)	0.59
Axis 2	127.0 + 0.49 (location)	0.28
Axis 3	-26.9 + 36.5 (pH) - 2.1 (vegetation)	0.45
Total OTUs	1.5 - 0.11 (location) + 4.2 (pH)	0.47

Table 4.07. Significant correlations between species relative abundance and DECORANA axes (* P < 0.05, ** P < 0.01, *** P < 0.001).

	Axis I	Axis II	Axis III
Austroclima sepia	*(-)		*(+)
Coloburiscus humeralis		**(+)	**(+)
Nesameletus sp.			**(+)
Zelandobius confusus			*(+)
Zelandoperla spp.			***(+)
Early Instar Plecoptera		**(-)	
Stenoperla prasina		**(+)	**(+)
Austroperla cyrene			***(+)
Oxyethira albiceps	*(+)		
Helicopsyche sp.	***(+)	*(-)	
Pseudoeconesus sp.		*(-)	
Hydrobiosella stenocerca		*(+)	***(+)
Tiphobiosis sp.	*(-)		
Costachorema brachyptera			**(+)
Costachorema psaroptera	*(-)		
Costachorema callista			*(+)
Psilochorema bidens	*(+)	**(-)	
Psilochorema tautora		*(-)	
Early Instar Hydrobiosidae			*(+)
Paranephrops zealandicus			*(-)
Paratya curvirostris		*(-)	
Hydrophilidae	***(-)		
Hydraenidae		*(+)	***(+)
Scirtidae sp.A	*(-)		
Scirtidae sp.C	**(-)	*(-)	
Elmidae (*Hydora* sp.)			***(+)
Potamopyrgus antipodarum	**(+)	***(-)	
Chiltonia rivertonensis	***(-)		
Paraleptamphopus subterraneus	*(-)		**(-)
Paracalliope sp.			*(+)
Oligochaeta	***(+)		
Acarina	*(-)		*(-)
Chironomidae	***(+)		
Empididae			*(+)
Eriopterini		*(-)	*(+)
?Tanyderidae sp.		**(-)	
Unknown Diptera			***(-)
Stratiomyidae			**(-)

Scirtidae sp. C. and Hydrophilidae were strongly correlated with moss and high conductivity.

Axis 2 was significantly correlated with site location, conductivity, maximum surface current velocity, and vegetation (Table 4.05). However, only site location was retained as a key variable and it yielded a regression equation with an r^2 value of 0.28 (Table 4.06). Species positively correlated with axis 2 were strongly represented in the upper Rakeahua Valley and on the east coast between the Yankee and Murray Rivers (Fig.4.04). Negatively correlated taxa were common in the lower Rakeahua and north west coast.

Axis 3 was correlated with pH, DOC concentration, percentage moss cover, width, site location and vegetative cover (Table 4.05). Again these variables were intercorrelated and only pH and vegetation were significant enough to be retained as key variables. Alone, pH yielded a regression equation with an r^2 value of 0.29, whereas combined with vegetation $r^2 = 0.49$ (Table 4.06).

Species whose abundances were positively correlated with axis 3 (Table 4.07) were commonest in circumneutral waters and podocarp forest. A total of 18 taxa were positively correlated with Axis 3 (Table 4.07) including *A. cyrene* which is known to be intolerant to long periods of exposure to low pH (Collier 1988). Only four taxa were negatively correlated with axis 3; these were commonest in acidic waters, and were often associated with coastal scrub. Of the four (*Paraleptamphopus subterraneus*, *Paranephrops zealandicus*, Acarina, and an unidentified dipteran) the first belongs to a genus with known acid-tolerant representatives (Collier *et al.* 1989), and Ball (1987) has documented the ability of the crayfish, *P. zealandicus* to withstand very low acidities.

Numbers of taxa collected from individual sites ranged from nine to 43. Taxonomic richness was significantly correlated with location ($P < 0.01$), vegetation ($P < 0.01$) and pH ($P < 0.1$, Table 4.05). However, only location and pH were retained by stepwise regressions (0.05 level of significance) and together they yielded a regression equation with $r^2 = 0.47$ (Table 4.06). Location alone yielded a regression equation with $r^2 = 0.38$.

Accurate functional feeding group classification of many members of the New Zealand stream fauna is not easy because they are generalists that feed on a wide range of food materials (Winterbourn and Collier 1987, Winterbourn 1987). Nevertheless, it is apparent that the Stewart Island stream fauna is dominated by a preponderance of collector-browsers and predators as in many mainland New Zealand streams.

Triplectides, *Austroperla cyrene*, *A. benhami* and possibly *Pseudoeconesus* were the only large shredder taxa collected from Stewart Island, and of them it is likely that only the former is an obligate shredder. *Triplectides* and *Pseudoeconesus* were never found in large numbers (always < 1 % of faunal numbers) and were present in only 15.6 % of all samples. In contrast, *A. cyrene* was widespread (60 % of all sites Table 4.02) and made up to 12.4 % of the fauna at some sites, e.g., Site 44 where a larval density of 124 m^2 was recorded. The omnivorous, *Austridotea benhami* was probably an important shredder of woody material at lowland sites.

DISCUSSION

Throughout Stewart Island, the benthic invertebrate faunas of streams are remarkably similar, and numerically they are dominated by a common core of taxa, including *Chiltonia rivertonensis*, Oligochaeta, Chironomidae, *Deleatidium*, *Zelandobius*, *Zelandoperla* (*agnestis/fenestrata*), *Austroperla cyrene*, *Hydrobiosella stenocerca*, Hydrobiosidae, Simuliidae, and Scirtidae. They were members of the top five taxa list and occurred at over 50 % of sites sampled. Stewart Island's common core of taxa contrasts with the common core of genera (*Deleatidium*, *Coloburiscus*, *Nesamaletus*, (Ephemeroptera), *Stenoperla*, *Zelandoperla*, *Zelandobius*, (Plecoptera), *Hydrobiosis*, *Psilochorema*, *Pycnocentria*, *Olinga*, *Aoteapsyche*, (Trichoptera), *Archichauliodes* (Megaloptera), *Potamopyrgus* (Gastropoda)), and species, that Winterbourn *et al.* (1981) suggested dominated unmodified streams in New Zealand, and to which Quinn and Hickey (ms) proposed that *Pycnocentrodes*, Eriopterini, and *Conuxia* should be added. *Olinga*, *Conuxia*, *Pycnocentrodes* and *Archichauliodes* are rare or absent on Stewart Island, and *Nesamaletus*, *Stenoperla*, *Psilochorema*, *Pycnocentria*, *Aoteapsyche*, and Eriopterini are uncommon and have limited distributions. In fact, of the latter only *Stenoperla* was a member of the top five taxa at any site. Furthermore, *A. cyrene*, *Hydrobiosella*, and Scirtidae, appear to be restricted to fewer

localities on the two main islands of New Zealand than Stewart Island. These three taxa were present at less than 26 % of the 45 sites sampled by Rounick and Winterbourn (1982) from around New Zealand, and amphipods were recorded at less than 15 % of their sites.

Available evidence suggests that the presence of moss has a major influence on community composition on Stewart Island. Samples taken in my surveys included animals from all available habitats at a site and the relative abundance of taxa appears to have been influenced by the amount of moss sampled. Bryophytes can support up to 30 times more invertebrates than stony habitats (Maurer and Brusven 1983, Suren 1988) and the strong correlation found between percentage moss cover and the abundance of *C. rivertonensis* and Hydrophilidae, and the negative correlation between Oligochaeta, Chironomidae, *Potamopyrgus* and *Helicopsyche* and DECORANA axis 1, supports this contention.

Conductivity, which appears to be strongly influenced by wind blown, sea salt on Stewart Island, was also significantly correlated with assemblage structure. Extremes of conductivity on Stewart Island were nearly an order of magnitude greater than values reported by Winterbourn and Collier (1987) for unpolluted sites on the west coast of the South Island, and were primarily a consequence of increased salinity. It is well known that freshwater invertebrates cannot tolerate even mildly saline waters (Macan 1963), and the distinctive coastal stream group (Group 5) identified by cluster analysis is assumed to consist of species that are relatively insensitive to this factor. Certainly, one of the most common species in this group, *Oxyethira albiceps* is known to be tolerant of a wide range of environmental extremes (Patrick *et al.* 1989)

Locality and pH also affected community composition, and were the only factors significantly correlated with taxonomic richness of communities. This is consistent with the findings of Winterbourn and Collier (1987) and Collier *et al.* (1989), and supports the notion that availability of suitable colonisers at a particular locality sets the upper limit to species richness.

Finally, Rounick and Winterbourn (1982) suggested that forested stream reaches having Pfankuch (1975) stability ratings of less than 100 (86 % of survey sites on Stewart Island) were most likely to support

populations of invertebrate shredders, and Quinn and Hickey (ms) found that shredders were most abundant in streams with a high percentage of catchment in forest and scrub. Both of these observations suggest that many Stewart Island streams might be expected to contain species of shredders.

It was therefore surprising to find that obligate shredders were uncommon and only locally distributed on Stewart Island. Shredders never numerically dominated stream faunas and rarely exceeded more than 10 % of total relative abundance. *A. cyrene* was the only species that was widely distributed, and although it was at times an important component of the fauna, it is only a faculative shredder.

SUMMARY

Taxonomically, the Stewart Island macroinvertebrate fauna is characterised by a large number of taxa that are also common on the mainland and only a few trichopteran and plecopteran species appear to be endemic to the island. An outstanding feature is the absence, or relative rarity of a number of important mainland families and genera including the Notonemouridae, Conoesucidae and *Archichauliodes*. These absences suggest that little gene flow occurs between South and Stewart Islands, and that Foveaux Strait represents a significant barrier to colonisation. However, the development of a degree of endemism in the aquatic fauna has probably been restricted by the relatively short period of isolation, following Stewart Islands separation from the south Island at the end of the Otira glaciation 10,000 years ago (McGlone 1980).

One of the most distinctive features of the Stewart Island stream fauna is the dominance of a common core of taxa in many streams. This core differs from its mainland equivalent because of the importance of *Chiltonia rivertonensis*, *Austroperla cyrene*, Scirtidae, and *Hydrobiosella stenocerca*, taxa that are less commonly encountered on the two main Islands of New Zealand, and also because of the absence or rarity of some important mainland common core genera, *Olinga*, *Conuxia*, *Pycnocentrodes* and *Archichauliodes*. Numerically, Stewart Island's fauna is dominated by Amphipoda, Chironomidae and Oligochaeta, with the mayfly genera, *Deleatidium*, *Austroclima* and *Coloburiscus*, gripopterigid stoneflies, Coleoptera (Scirtidae and Elmidae) and Simuliidae, of secondary

importance. Cased caddisfly larvae are rare, whereas the philopotamid *Hydrobiosella* and Hydrobiosidae are encountered, frequently. The isopod, *Austridotea benhami* is a conspicuous component of many coastal streams on the eastern side of the island, including those flowing into Paterson Inlet and Port Pegasus. Functionally, the islands stream fauna is dominated by collector-browsers, and with the exception of *A. cyrene*, shredders are uncommon.

Geographically, streams of the north east coast have similar faunas to those in the Rakeahua Valley, but they differ from those of the west and north west. The characteristic faunas of the former two areas appear to be related to similarities in pH, conductivity, and vegetation, but correlations with these variables were not strong. The abundance of bryophytes in streams also appears to have a major influence on community composition throughout the Island.

In summary, it is apparent that Stewart Island's stream faunas are distinctive, but the distinctiveness is one of degree and not of kind. My findings from lowland Stewart Island streams draining forested catchments, do not provide any evidence that a unique lowland fauna existed in New Zealand prior to human colonisation, but rather they support the contention that New Zealand stream faunas are dominated by a number of generalist and opportunistic species (Winterbourn 1986).

CHAPTER 5

LEAF BAG COLONISATION EXPERIMENT

INTRODUCTION

It has been suggested that benthic animal communities in small forested streams depend primarily on allochthonous inputs in the form of leaves, twigs, and wood as their primary source of food (Cummins 1974). If so, studies of the processing of heterotrophic inputs are of fundamental importance for increasing our understanding of stream ecosystems (Rounick and Winterbourn 1983). Research in this field has focussed on the physical and biological factors that affect breakdown of allochthonous inputs, particularly leaf litter, and to a lesser extent wood (see Anderson and Sedell 1979 for a review, Rounick and Winterbourn 1983). Conflicting evidence concerning the importance of various physical parameters including temperature, water velocity and dissolved nutrient concentrations on litter breakdown has been found (Rounick and Winterbourn 1983), but numerous studies have demonstrated the importance of large particle detritivores (i.e., shredders) in this process (e.g., Peterson and Cummins 1974, Davis and Winterbourn 1977, Collier 1988).

Recently, there has been considerable interest in the effects of low pH on aspects of stream ecosystem structure and function, and in several studies decomposition rates have been found to be slower in acidic than circumneutral waters (Hildrew *et al.* 1984, Allard and Moreau 1986). These Northern Hemisphere studies have provided the impetus for work in New Zealand on the effects of naturally acidic brown waters, and the role of humic substances on microbial conditioning, invertebrate colonisation and litter decomposition (Collier 1988). Results obtained by Collier indicate that breakdown rates are also slow in these waters of low pH. Kamahi (*Weinmania racemosa*) leaves were used in his experiments, as it is a common riparian species in South Westland where the studies were done, and it also represents an important source of leaf litter to Stewart Island streams (see Chapter 2).

My initial survey of Stewart Island streams (Chadderton 1988) indicated that although many of them were brown waters with similar DOC concentrations to those in South Westland, they were less acidic (pH 6.0 - 7.2) and had higher conductivities. In that survey I also found that their benthic invertebrate faunas were similar to those reported from

various parts of Westland (Cowie 1980, Winterbourn and Collier 1987), although a number of taxa with restricted distributions on the mainland were present. One of these, *Austridotea benhami* was often abundant in leaf packs, and was commonly associated with woody debris.

In the present study, I examined invertebrate colonisation patterns and rates of breakdown of kamahi leaves at six stream sites in the Rakeahua River Valley. Two sites were in small headwater streams, and were used so that direct comparisons could be made with the results obtained by Collier (1988). Another four sites were in lowland streams so that the role of *A. benhami* in leaf breakdown could be examined.

METHODS

Living, green, kamahi leaves were collected from a single tree near Halfmoon Bay in December 1988. In the laboratory, 5 g of leaf material was placed in bags of two mesh sizes:

(1) 7 mm mesh bags (15 x 14 cm, also described as coarse mesh bags from here on) that allowed free access to all macroinvertebrates

(2) PVC tubes (10 cm long, 4 cm diameter, also described as controls from here on) covered at both ends by 0.2 mm mesh to exclude macroinvertebrates.

All bags were sealed and oven dried for seven days at 50°C. Dried leaves from six bags were then reweighed (to the nearest 1 mg) on a Mettler PC Top Pan balance to obtain an estimate of initial dry weight.

Sets of 12 leaf bags and 12 controls were placed in commercial grade onion sacks at six sites in the Rakeahua River (Fig 5.1) between 3 and 5 January, 1989. Another set of 5 leaf bags and 5 controls was not placed in the streams but otherwise was treated the same and were returned to the University of Canterbury and reweighed to determine if any leaf biomass losses could be attributed to storage and transport. Neither group differed significantly from those weighed immediately after filling and drying (Kruskal-Wallis ANOVA, $P > 0.5$) indicating that storage and transport losses had negligible effects on weight loss.

Sets of 3 leaf bags and controls were removed from each site after about 62, 122, 220 and 308 days ($\pm$ 4 days) in the field. On removal from the onion sack, the contents of each bag/tube were placed in a separate plastic bag and stored in 4-10 % formalin. In the laboratory, leaves were washed over a 0.14 mm mesh sieve to remove fine debris and silt, dried (7

days at 50°C) and weighed. Invertebrates collected on sieves were identified and counted.

Kruskal-Wallis nonparametric ANOVAs were used to test for significant differences in dry weights of leaves ($P < 0.05$) among dates, groups of sites, and pairs of sites (Statistix NH Analytical Software). Decay coefficients (-k) for leaves were calculated using the exponential decay model of Peterson and Cummins (1974);

$$-k = \log_e(\%R/100)/t$$

where R = amount of leaf material remaining after t days in the stream.

Half lives of leaves (time to 50 % weight loss) were also calculated.

Scanning electron microscopy

Leaves removed from bags at all sites after 220 days, and from leaf bags and controls after 62, 122 and 220 days at Site 1, were examined by scanning electron microscopy (SEM) to enable a qualitative assessment of microbial colonisation and leaf surface breakdown to be made.

Sections (about 1 cm^2) were excised from leaves and placed in 2.5 % glutaraldehyde in 0.1 M sodium cacodylate buffer (pH 7.4). Following rinsing in buffer overnight, the specimens were post-fixed in 2 % osmium tetroxide for 8-18 hours at 4°C. After rinsing in buffer solution for another 8-10 hours, specimens were dehydrated in a graded alcohol series; 50-100 % ethanol, about 2 hours in each solution, with a final period of 18 hours in 100 % ethanol. Leaf material was then transferred to amyl-acetate after passing it through a 4 step ethanol/amyl-acetate series (2 hours in each solution; over-night in a fresh solution of 100 % amyl-acetate). After drying in a liquid CO_2 critical point drier, specimens were mounted on 2.5 cm diameter aluminium stubs using double sided cellotape or conductive carbon paint. Finally, they were sputter coated with 60 nm of gold and observed with a Cambridge Stereoscan MK 2 scanning electron microscope at an accelerating voltage of 20 kv.

Study sites

Six sites were chosen in the Rakeahua Valley (Fig. 5.1). Site 1 was in a small (< 1.5 m wide) circumneutral, clearwater stream flowing through podocarp forest (Table 5.1, Plate 5.1B). Site 2 was also in a small (1.5 m wide) stream but had slightly acidic, brownwater (Table 5.1) and flowed through podocarp forest (Plate 5.1A). Site 3 was on one of

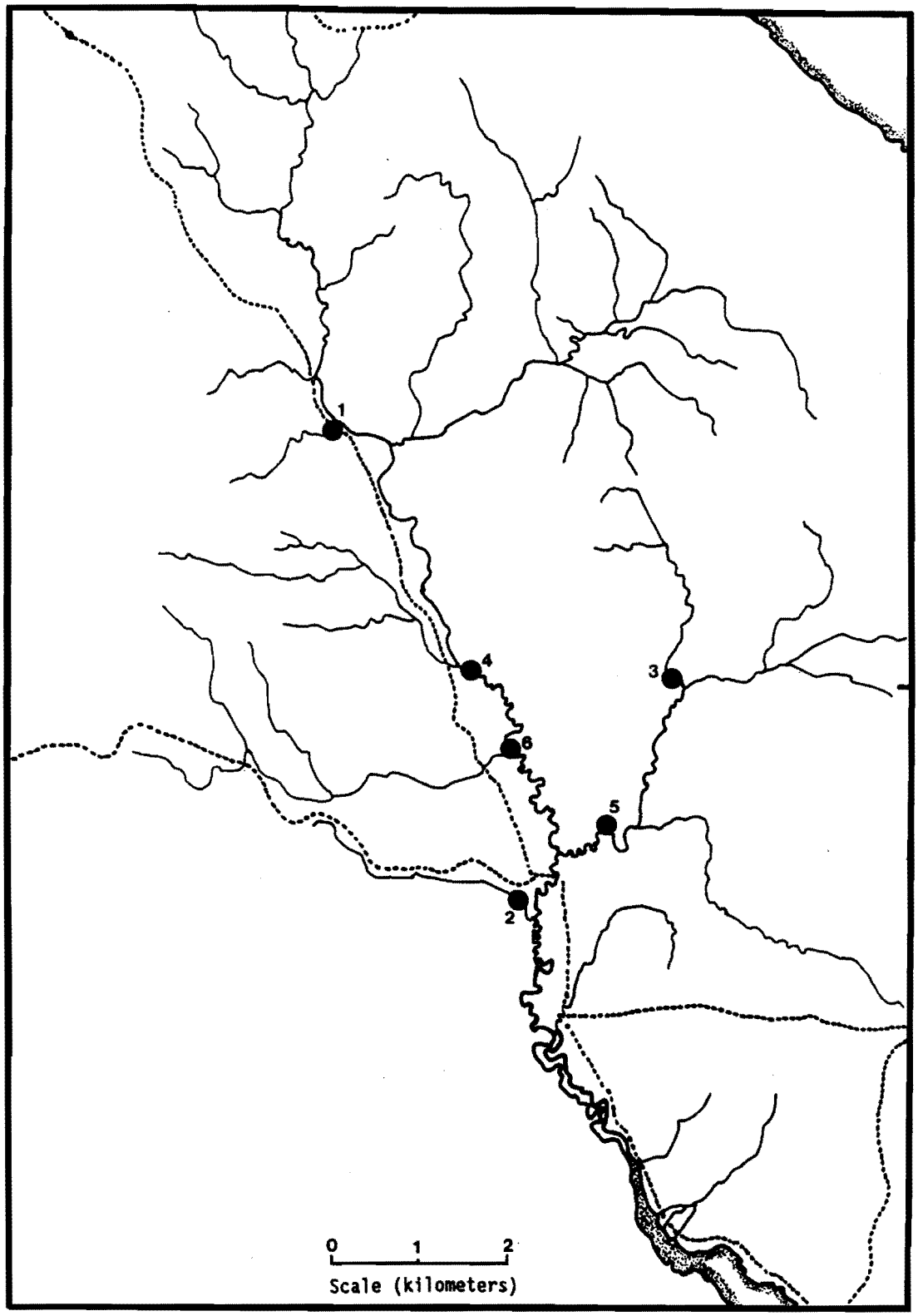


Fig. 5.1. Leaf pack colonisation sites in the Rakehua River Valley.

Table 5.1. Average and range (in brackets) of values of physicochemical parameters measured from water samples collected when collecting leaf bags. Addition samples collected at some sites during the year (N = number of samples).

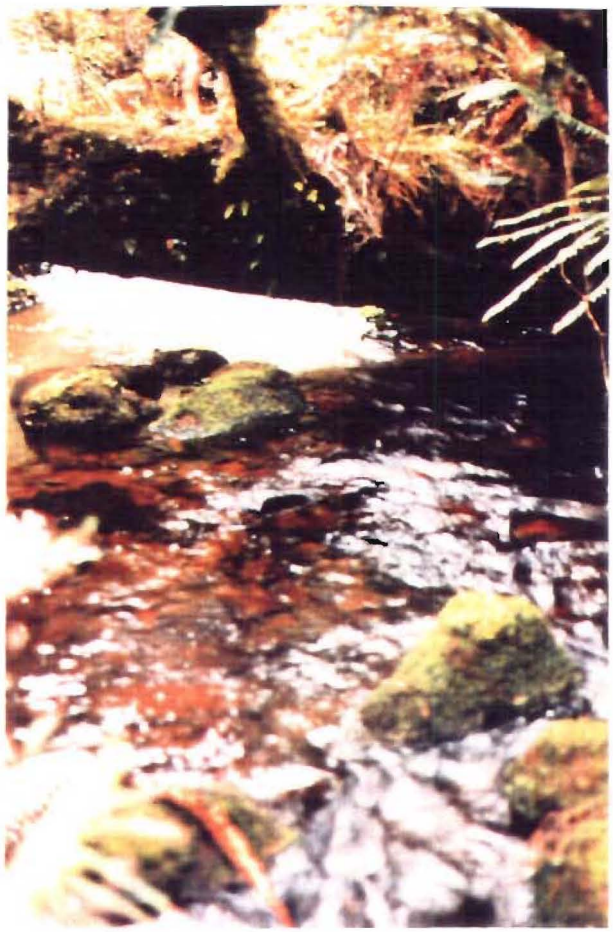
Sites	N	pH	Conductivity ($mS\ m^{-1}$)	DOC conc. ($g\ m^{-3}$)	Alkalinity ($g\ m^{-3}\ CaCO_3$)
1	5	6.8 (6.4-7.0)	18.5 (16.8-19.0)	6.3 (4.9-9.7)	12.9 (6.9-16.5)
2	6	6.6 (6.2-6.9)	13.9 (11.8-15.1)	7.3 (5.9-10.9)	6.7 (3.7-10.0)
3	4	6.4 (6.0-6.7)	20.9 (19.0-22.3)	9.2 (5.9-12.8)	11.0 (7.8-13.4)
4	5	6.5 (5.9-6.8)	18.3 (15.9-20.1)	9.9 (7.0-15.9)	9.2 (4.9-13.5)
5	4	6.6 (6.2-6.7)	19.6 (17.9-22.0)	8.4 (6.2-10.5)	11.1 (6.5-14.2)
6	5	6.5 (6.1-6.8)	18.5 (14.7-20.2)	9.6 (6.6-15.5)	9.3 (4.9-12.5)

Plate 5.1A Site 2 ("Stream One") a small (1.5 m wide) stream in the lower Rakeahua Valley.

Plate 5.1B Site 1 ("Stream 8") a small (1 m wide) stream in the upper Rakeahua Valley.

Plate 5.1C Leaf material after 120 days submersion, from 7 mm mesh leaf bags kept at Site 1.

A



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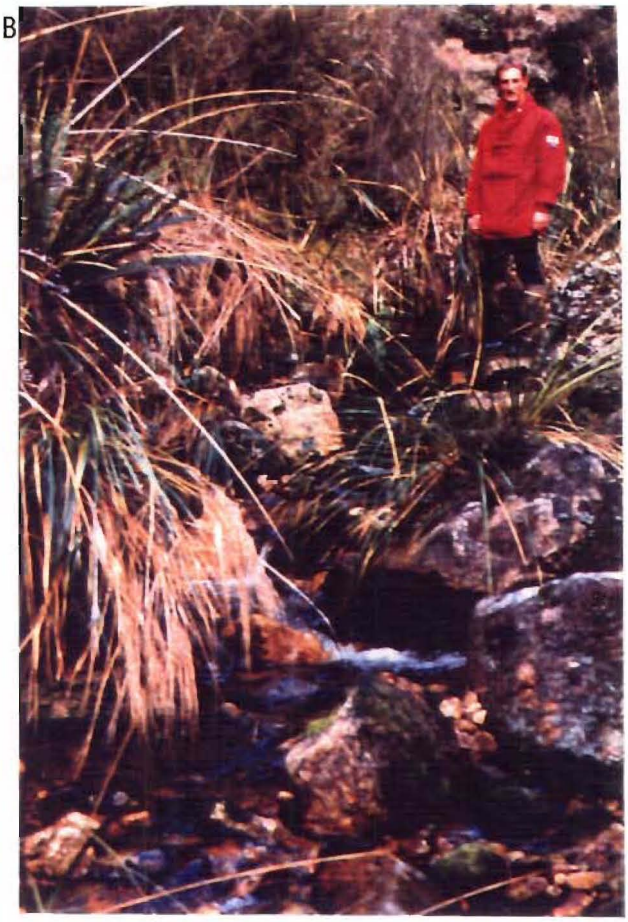


C

the main tributaries of the Rakeahua Mt./Trail Hill branch of the main river. A 3rd-4th order stream, it also flowed through podocarp forest and had slightly acidic brownwaters (Table 5.1, Plate 5.2D). Sites 4 and 6 were sited on the main branch of the Rakeahua River where the riparian vegetation was manuka with a mixed shrub understorey. At both of these sites the river was sluggish and meandered across the flood plain. The wide stream channel (6-7 m) was choked with manuka logs and debris (Plates 5.2A & B), and the substratum was predominantly coarse sand. Both sites had slightly acidic waters with moderate DOC concentrations (Table 5.1). Site 5 was sited in the mainstem of the Rakeahua Mt./Trail Hill branch of the Rakeahua River (Plate 5.2C). Riparian vegetation was a mixture of manuka and totara with ground cover dominated by *Blechnum* ferns. Here the onion sack was placed in a side eddy at the end of a riffle where the river was about 10 m wide.

Sites 1 and 2 were used to make comparisons with Collier's (1988) results, whereas Sites 5 and 6 had abundant populations of *Austridotea*. Sites 3 and 4 were used to make comparisons with Sites 5 and 6 as neither was thought to harbour *Austridotea*.

Water temperature was recorded at Sites 1 and 2, and at a site about 2 km downstream of Site 5, using maximum/minimum thermometers, which were read and reset on each sampling date. Over the course of the experiment, temperatures ranged from 6-10°C and 1.5-14°C at Sites 1 and 2, respectively. Temperature records at the mainstem site ranged from 4.5-15°C.

RESULTS

Weight loss of leaves

Weight losses of leaves after 62-66 days in 7 mm mesh bags averaged 38.5 % of initial dry weight and were not significantly different among sites (Fig. 5.2). Some signs of feeding were apparent, although only at Sites 3 and 4 were weight losses significantly greater in 7 mm mesh bags than in 0.2 mm mesh bags (Kruskal-Wallis ANOVA, $P < 0.05$). After 122 days immersion, considerable skeletonisation of leaves was noted in coarse mesh bags, particularly at Site 1 where veins and petioles were all that remained of most leaves (Plate 5.1C). At all sites, leaves were soft and beginning to fall apart by this time, and the upper epidermis

Plate 5.2A Site 6, the lower mainstem site.

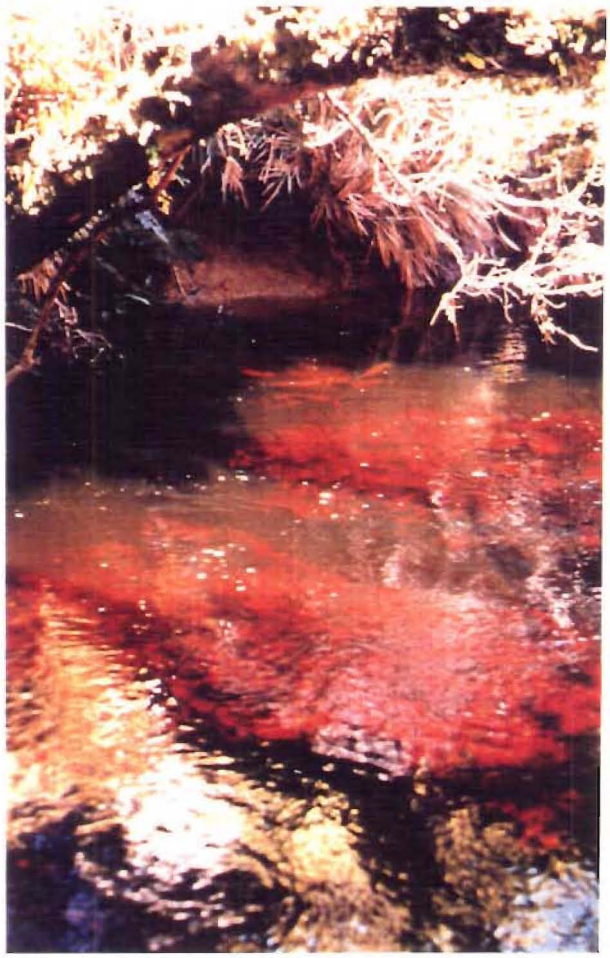
Plate 5.2B Site 4, the upper mainstem site.

Plate 5.2C Site 5, the lower site in the Rakeahua/Traills Hill branch of the Rakeahua River.

Plate 5.2D Site 3, the upper site in a tributary of the Rakeahua/Traills Hill branch of the Rakeahua River.

A

B



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D

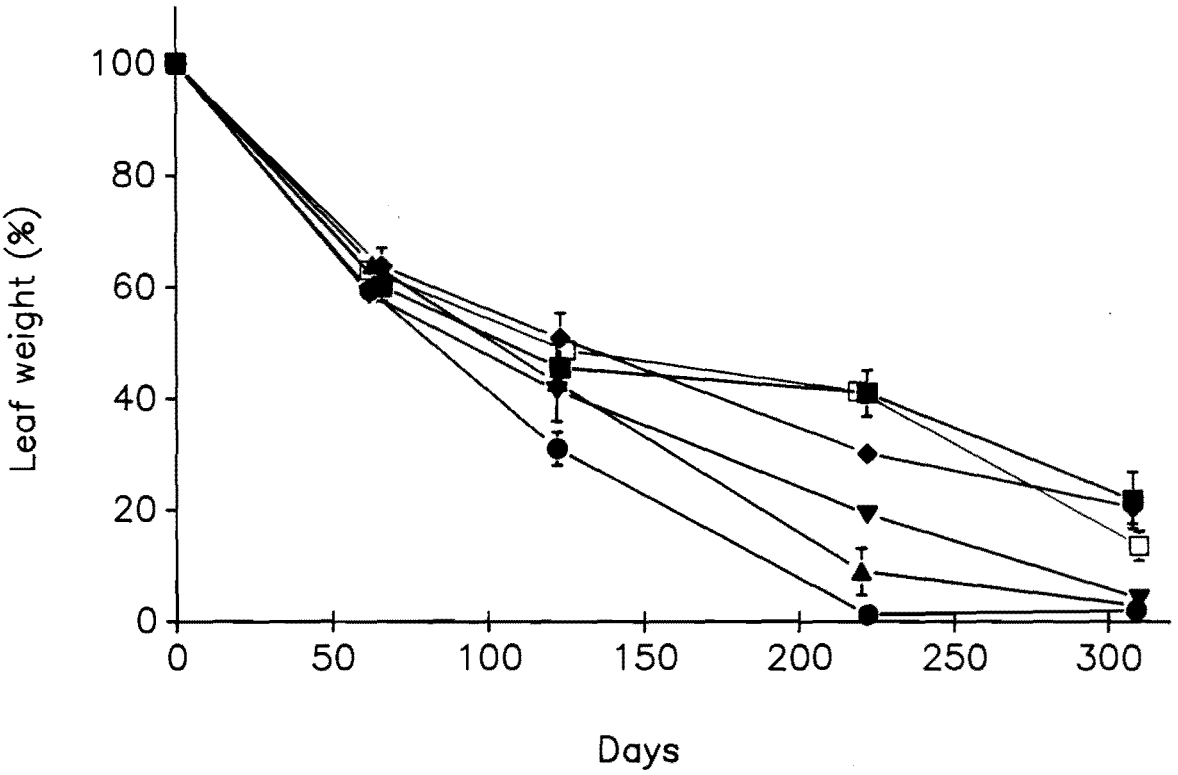


Fig. 5.2. Percentage initial dry weight of leaves remaining ($\bar{X} \pm 2SE$, N = 3) in 7 mm mesh bags kept in Sites 1 (●), 2 (▲), 3 (■), 4 (▼), 5 (◆), and 6(□) in the Rakeahua River valley, Stewart Island.

had begun to slough off. In contrast, leaves in the control tubes were intact and solid. After 122 days, weight losses in coarse mesh bags at Site 1 were significantly greater ($P < 0.05$) than at all other sites except Site 2 where losses were highly variable among bags (Fig 5.2).

After 220 days, differential leaf losses were more apparent (Fig. 5.2) and two groups of sites could be identified on the basis of leaf breakdown rates. Thus, weight losses of leaves were significantly greater at Sites 1, 2, and 4 than at Sites 3, 5, and 6 ($P < 0.05$). At Site 1, no leaf material remained except for some fragments jammed into the tight corners of the leaf bags. The lower weight losses recorded at Sites 3 and 6 at this time were a consequence of the presence of fine silt and sand that could not be removed by gentle washing, and also the presence of chironomid tubes attached to leaf surfaces.

By day 308, coarse mesh bags at Sites 2 and 4 were also almost completely devoid of leaf material (2.9 % and 4.2 % of initial weight remaining, respectively), whereas at Sites 3, 5 and 6 an average of 18.6 % of initial leaf mass remained in the 7 mm mesh bags (Fig. 5.2).

Leaf weight losses were consistently lower in 0.2 mm mesh tubes than 7 mm mesh bags throughout the experiment, and by day 308 the average loss in them was only 44.3 % (Fig. 5.3). Weight losses at Site 1 were significantly lower ($P < 0.05$) than at the five other sites, and 61.9 % of the leaf material was still present after 308 days in the stream. Weight losses at the other sites were not significantly different.

Calculated decay rates (-k) for coarse mesh bags (Table 5.2) ranged from 0.0049 to 0.0199, and were fastest at Sites 1, 2, and 4. Half lives (T50) of leaves in coarse mesh bags at the 6 sites ranged from 80 to 125 days.

Colonisation of leaf bags by invertebrates

Forty seven invertebrate taxa were recorded from 7 mm leaf bags at the six sites (Table 5.3). The number of colonising taxa was lowest at Sites 1 and 2 (15 and 18, respectively), whereas 24-28 taxa were recorded from each of the other four sites. Chironomidae were common at all sites, and accounted for over 70 % of the colonising individuals at Sites 2, 3, and 4. Far fewer chironomid larvae were recorded at Site 1, where they represented less than 4 % of the fauna. In contrast, the shredder, *Austroperla cyrene* was most abundant at Site 1. The isopod, *Austridotea benhami*, which also feeds on woody and possibly leaf material (see

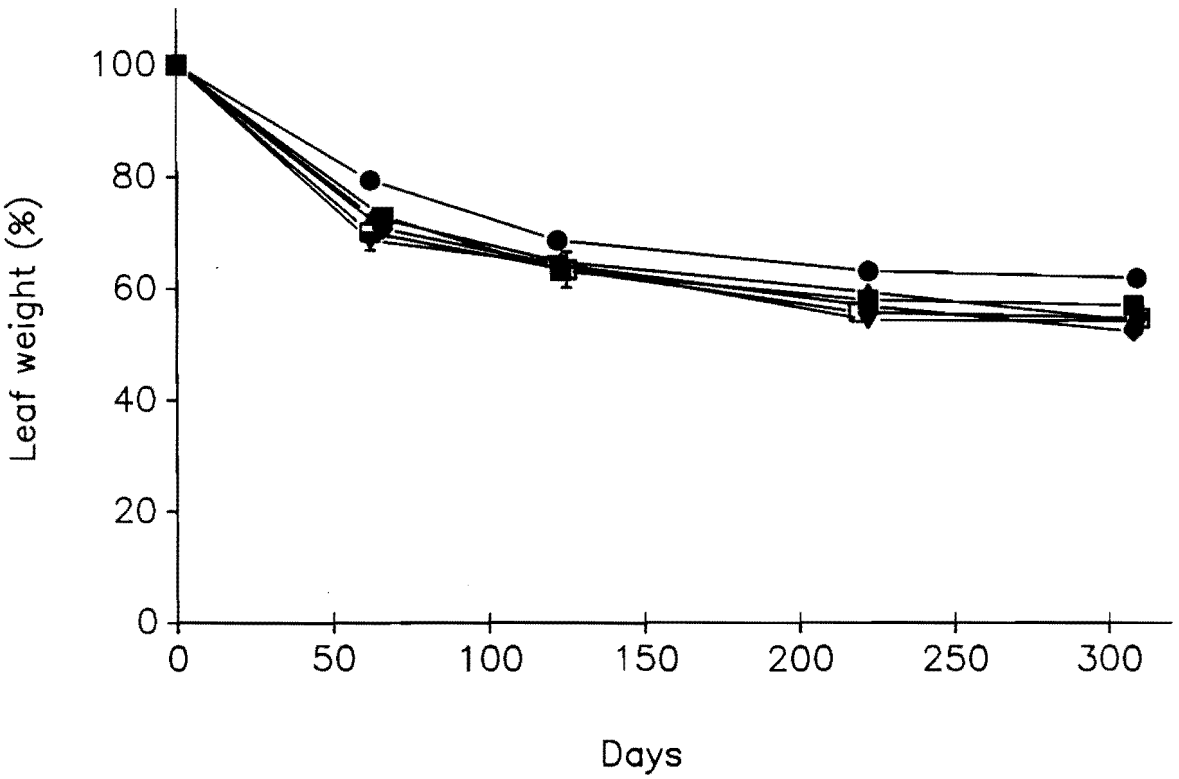


Fig. 5.3. Percentage initial dry weight of leaves remaining (X ± 2SE, N = 3) in 0.2 mm mesh tubes kept in Sites 1 (●), 2 (▲), 3 (■), 4 (▼), 5 (◆), and 6(□) in the Rakeahua River valley, Stewart Island.

Table 5.2. Decay coefficients (-k) and half-lives (T_{50}) of leaves held in 7 mm mesh leaf bags and 0.2 mm mesh tubes from six sites in the Rakeahua River, Stewart Island.

	Leaf bag (7 mm mesh)		Control (0.2 mm mesh)
Site	(-K)	T_{50}	(-K)
1	0.0199	80	0.0016
2	0.0105	92	0.0020
3	0.0049	103	0.0018
4	0.0102	120	0.0018
5	0.0051	125	0.0021
6	0.0064	115	0.0019

Table 5.3. Relative abundance and numbers of invertebrates colonising 7 mm mesh leaf bags removed from sites in March, May, August and November (all bags combined). Actual numbers collected in brackets.

	1	2	3	4	5	6
EPHEMEROPTERA						
*Deleatidium*spp.	0.5(1)	1.7(5)	7.6(83)	2.2(12)	6.5(24)	1.4(8)
Mauiulus luma	0.5(1)	0.7(2)				
Zephlebia spectabilis				0.4(2)		0.7(4)
Neozephlebia scita		0.7(2)	0.3(4)	0.4(2)		0.5(3)
Austroclima sp.		*0.7(2)*	*2.1(23)*	*0.2(1)*		
Coloburiscus humeralis			0.8(9)	0.4(2)	0.3(1)	
PLECOPTERA						
Stenoperla prasina			0.1(1)			
Austroperla cyrene	14.6(29)	3.4(10)	0.6(7)	1.5(8)	0.5(2)	
Megaleptoperla grandis	2.5(5)	1.4(4)	0.1(1)	0.6(3)	1.6(6)	0.7(4)
Zelandoperla spp.		0.3(1)	0.3(3)	0.2(1)	0.3(1)	0.2(1)
Zelandobius confusus	9.5(19)		2.3(3)	0.6(3)		22.2(12)
Zelandobius furcillatus	11.6(23)	1.4(4)	0.2(2)	0.2(1)	0.5(2)	1.8(10)
Acroperla sp.			0.5(6)	0.8(3)		
Cristaperla fimbria						0.2(1)
Early instar Plecoptera			0.3(4)	0.3(1)	0.2(1)	
TRICHOPTERA						
Hydrobiosidae		1.0(3)	1.8(20)	0.2(1)	1.9(7)	0.2(1)
Hydrobiosella stenocerca	0.5(1)					
Hudsonema aliena						1.3(7)
Triplectides dolichos				0.2(1)		
(?)Ecnomidae/Psychomyiidae						0.2(1)
DIPTERA						
Ceratopogonidae	0.5(1)		0.3(3)	2.4(13)	0.5(2)	7.7(43)
Chironomidae Larvae	37.7(75)	71.6(210)	70.5(774)	79.7(429)	56.9(211)	46.7(260)
Pupae	1.5(3)	3.4(10)	1.5(16)	3.3(18)	1.6(6)	1.6(9)
Muscidae	0.5(1)				0.3(1)	
Limonia nigrescens				0.4(2)		
Aphrophila neozelandica			0.1(1)	0.2(1)	0.4(2)	
Paralimnophila skusei						0.2(1)
Eriopterini					0.3(1)	0.2(1)
Simuliidae		3.8(11)	0.3(4)		4.6(17)	
Empididae		2.0(6)	1.7(19)	0.9(5)	1.9(7)	0.7(4)
?Tanyderidae			0.8(8)		0.8(3)	
Unknown aquatic diptera			0.1(1)			
COLEOPTERA						
Elmidae			0.1(1)			
Scirtidae sp.C	0.5(1)		0.1(1)	0.2(1)	1.3(5)	1.9(11)
Hydraenidae			0.3(4)			
AMPHIPODA						
Paraleptamphopus caeruleus			0.1(1)			
Paraleptamphopus subterraneus	3.5(7)			0.2(1)	0.3(1)	
Chiltonia rivertonensis	13.6(27)	1.0(3)	0.3(1)		0.5(2)	
Paracalliope spl.					0.3(1)	0.2(1)
Unknown species.					0.3(1)	
ISOPODA						
Austridotea benhami				P	3.0(11)	2.5(14)
GASTROPODA						
Potamopyrgus antipodarum					1.1(4)	0.4(2)
Sphaerium noveazealandiae						0.2(1)
ACARINA		0.3(1)	0.3(3)	0.2(1)	0.8(3)	0.2(1)
NEMATOMORPHA				0.2(1)	0.3(1)	0.2(1)
OLIGOCHAETA	2.5(5)	6.1(18)	8.6(95)	5.4(29)	12.1(45)	27.2(152)
COPEPODA						0.2(1)
COLLEMBULA		1.0(3)				

(p = present but not recorded in leaf bags)

Chapter 4, Part I) colonised leaf bags at Sites 5 and 6, and although present at Site 4 in small numbers (it was not thought to occur there when the experiment was set up), it was not found in leaf bags at this site.

Patterns of colonisation varied among sites and invertebrate numbers were greatest at Site 3 on all days except the last (Fig. 5.4). At Sites 1 and 2 where leaf breakdown was most rapid, numbers of colonists peaked on days 62 and 122, respectively, but after that densities fell dramatically.

Few distinct shredder colonisation patterns were apparent. At Site 1, numbers of *A. cyrene* were high after 62 days (13, all bags combined), and peaked after 122 days (16). However, no larvae were present after this. In contrast, numbers of *A. cyrene* in bags at Sites 2 and 4 (the two other fast breakdown sites) were similar throughout the experiment although there was a decrease at Site 2 on the last sampling occasion. Likewise, *A. benhami* exhibited no distinct pattern of colonisation and numbers were low (3-6 all bags combined) on each of the first three sampling occasions at Sites 5 and 6.

Although 33 taxa were recorded from 0.2 mm bags (Table 5.4), 25 of them were represented by fewer than 10 individuals (all bags and dates combined). Almost all colonisers were small individuals that could be expected to pass through the fine mesh. Chironomidae and Oligochaeta were most abundant, followed by Scirtidae and Ceratopogonidae.

The low degree of variability in leaf breakdown rates in fine mesh tubes (Table 5.2, Fig. 5.3) suggests that invertebrates that entered them, generally had little effect on breakdown in particular bags. Therefore, weight losses of leaves recorded can probably be attributed primarily to microbial decomposition.

Leaf decoposition and microbial colonisation

Scanning electron microscopy of leaf surfaces after 63 days at Site 1 showed that leaves had intact epidermis that were generally free of foreign material (Plate 5.3A) and were colonised by only a few isolated microorganisms and diatoms (Plate 5.3B). After 122 days submersion, the epidermis of the leaves were still largely intact although greater accumulations of foreign material were apparent (Plate 5.3C), and

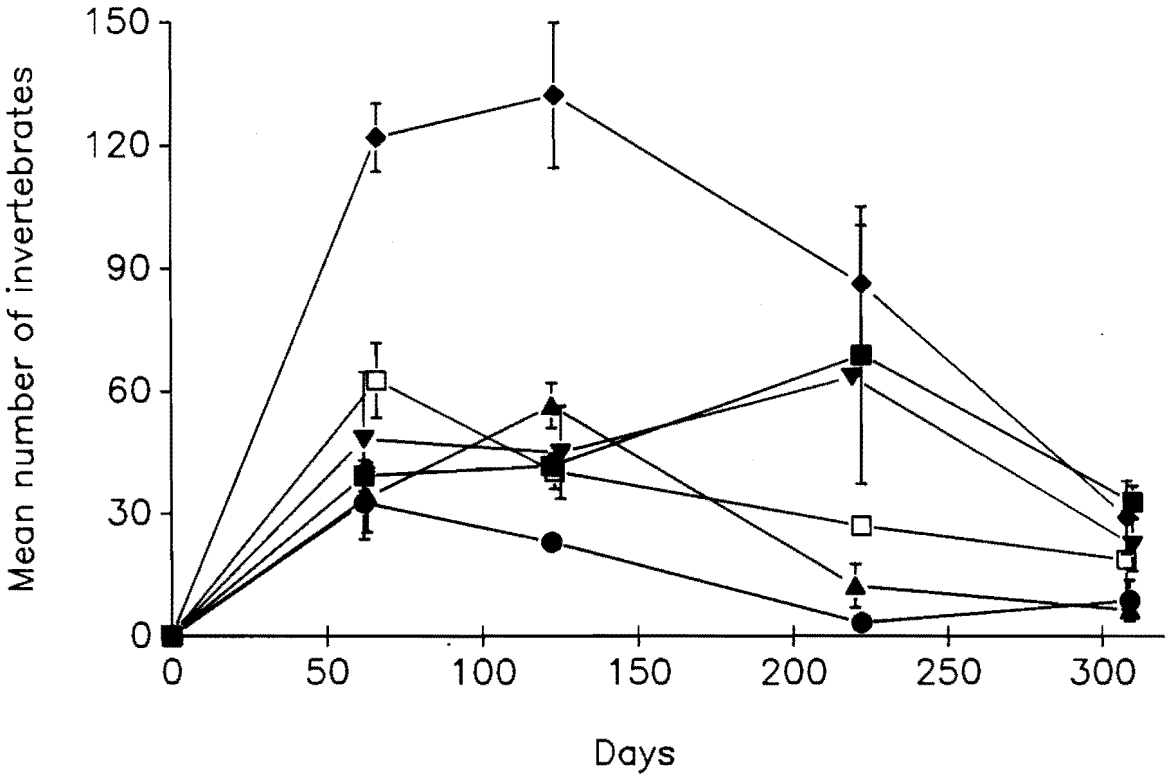


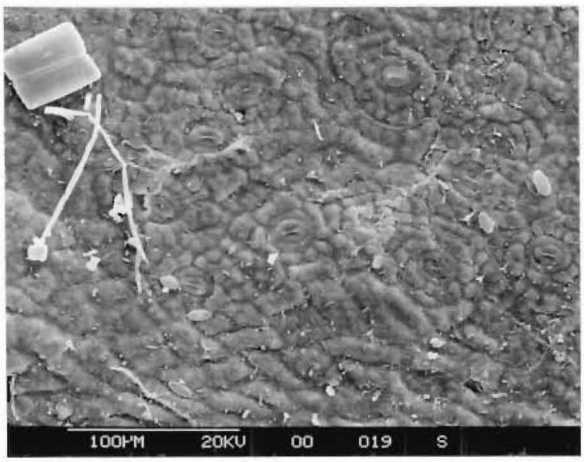
Fig. 5.4. Numbers of invertebrates colonising ($\bar{X} \pm 1SE$, N = 3) 7 mm mesh bags kept in Sites 1 (●), 2 (▲), 3 (◆), 4 (■), 5 (□), and 6(▼) in the Rakeahua River valley, Stewart Island.

Table 5.4. Numbers of invertebrates colonising 0.2 mm mesh tubes, removed from six sites in March, May, August, and November (all bags combined).

	1	2	3	4	5	6
EPHEMEROPTERA						
*Deleatidium*spp.		3	3		23	4
Neozephlebia scita					1	1
PLECOPTERA						
Austroperla cyrene		1				
Megaleptoperla grandis		1				
Zelandobius confusus		1	1	3	1	1
Zelandobius furcillatus		1				
Cristaperla fimbria	1					
Early instar Plecoptera		1				1
TRICHOPTERA						
Hydrobiosidae	1	2	6	2	3	2
Unidentified Leptoceridae		1				
Polyplectropus puerilis	1			2		
DIPTERA						
Ceratopogonidae	4	10	31	60	26	49
Chironomidae	192	393	154	211	373	215
Muscidae					1	1
Limonia sp.		1				
Aphrophila neozelandica			1	1		1
Paralimnophila skusei				2	2	
Hexatomini				1		
Simuliidae		1				
Empididae	4	7			3	11
Tanyderidae (*Miscoderus* sp.)				1		
?Tanyderidae						1
Stratiomyidae				1		
COLEOPTERA						
Elmidae		1				
Scirtidae sp.C	2	1		22	24	45
Hydraenidae		1		2		
AMPHIPODA						
Paraleptamphopus subterraneus	1					
Chiltonia rivertonensis	2	3		1	1	
ISOPODA						
Austridotea benhami						3
GASTROPODA						
ACARINA			3			
NEMATOMORPHA			1	1		3
OLIGOCHAETA	1	100	661	240	329	300
COPEPODA			2	1		2

Plate 5.3 The surfaces of leaves kept in 7 mm mesh bags after 63 days at Site 1 had intact epidermises that were generally free of foreign material (A) and were colonised by only a few diatoms and isolated microorganisms (B). After 122 days submersion the epidermises of the leaves were still largely intact although greater accumulations of foreign material were apparent (C), and filamentous microorganisms were commonly observed growing out of the leaves (D). After 220 days, however, the upper epidermis had gone (E) and it was clear that internal tissues had been colonised by microorganisms (F).

A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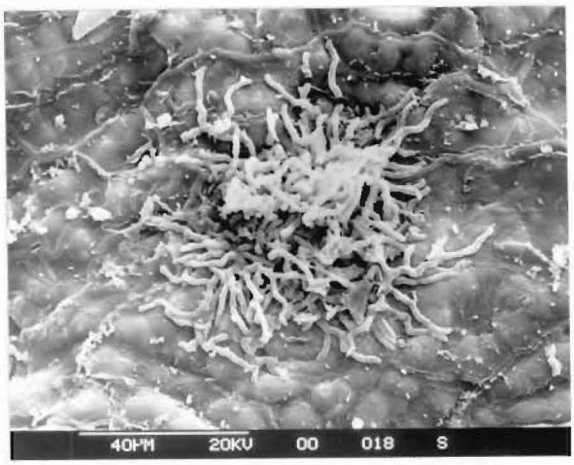
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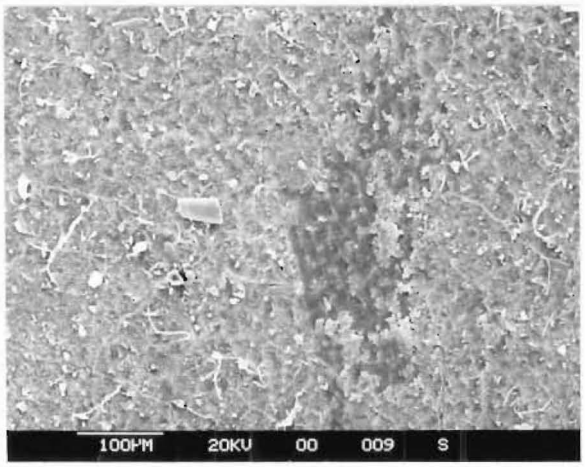
C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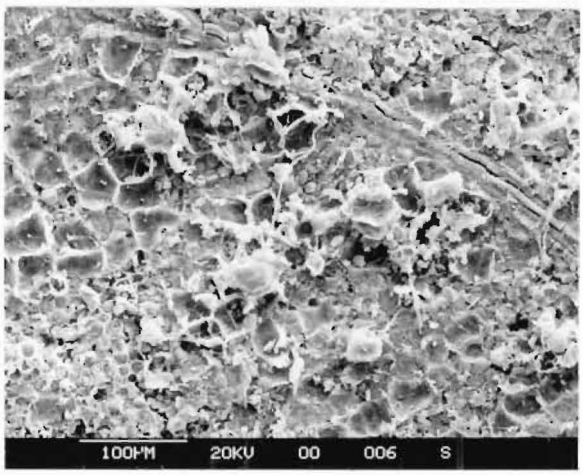
D


40µM 20KV 00 007 S

E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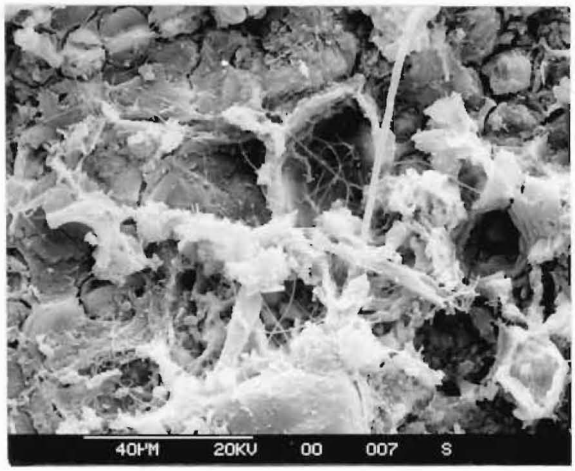
F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filamentous microorganisms were commonly observed growing out of the leaves (Plate 5.3D). After 220 days, however, the upper epidermis had gone (Plate 5.3E) and it was clear that internal tissues were colonised by microorganisms (Plate 5.3F). Similar patterns were observed on control leaves at Site 1 (Plates 5.4A & B), although the lower epidermis was still largely intact after 220 days and only the upper epidermis was beginning to show signs of breakdown.

Considerably greater microbial colonisation was observed at some of the other sites after 220 days submersion, particularly at Sites 4 and 5 (Plates 5.4C, D, E, & F). At these sites, intact epidermises (Plate 5.4C & E) and exposed pallisade cells (Plate 5.4D & F) were colonised by numerous small filamentous organisms probably actinomycetes, that projected out of the leaves. Larger filamentous organisms (Plate 5.4F & 5.3F) probably hyphomycetes, were also observed. The lower surfaces of a leaf examined from Site 3 was covered in a thick layer of amorphous material which seemed to protect the lower epidermis (Plates 5.5A B) from microbial colonisation. In contrast, the upper epidermis was missing (Plate 5.5C). Similarly, at Site 5 a thick layer of amorphous material interwoven with filamentous organisms including ?hyphomycetes was observed on the undersurface of a leaf (Plate 5.5D).

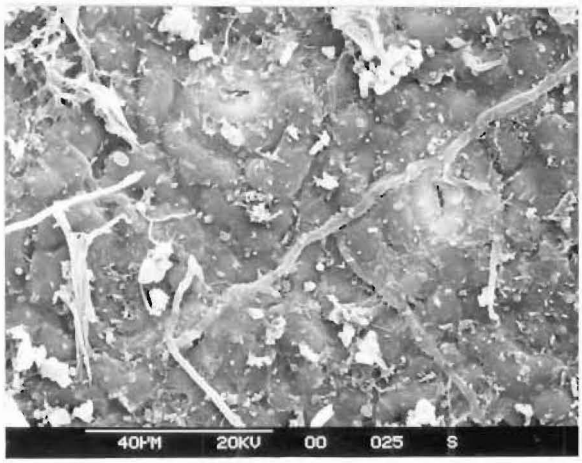
DISCUSSION

Rates of breakdown in 7 mm mesh bags at Sites 1, 2, and 4 fell within the fast ($-k > 0.010$) category of Peterson and Cummins (1974), whereas at Sites 3, 5, and 6 they fell around the cut off point ($\approx .005$) between the medium and slow categories. Decay coefficients for the slower groups are comparable to those reported by Collier (1988) for kamahi leaf packs in circumneutral, clearwater streams in South Westland, whereas the others were considerable higher.

Stream topography, temperature, discharge and aspects of water chemistry are known to affect leaf processing rates, either directly or indirectly by influencing microbial activity and invertebrate feeding (Anderson and Sedell 1979). However, it seems unlikely that these factors can explain differences observed between sites on Stewart Island and South Westland. Temperature cannot explain differences in breakdown rates between the two mainstem sites (Sites 4, and 6) as they were less

Plate 5.4 Leaves from 0.2 mm control tubes after 220 days submersion were still largely intact (A) and only the upper epidermis was beginning to show breakdown.
Considerably greater microbial colonisation of leaves from 7 mm mesh bags was observed at some of the other sites after 220 days submersion, particularly Sites 4 and 5 (C, D, E, & F). At these sites, intact epidermises (C & E) and exposed pallisade cells (D & F) were colonised by numerous small filamentous organisms probably actinomycetes, that projected out of the leaves. Larger filamentous organisms (F) probably hyphomycetes, were also observed.

A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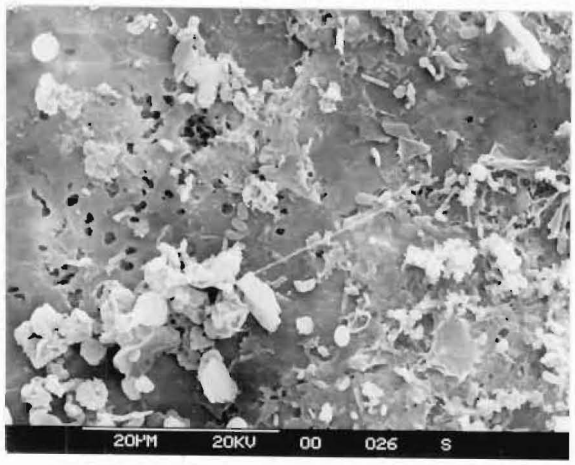
B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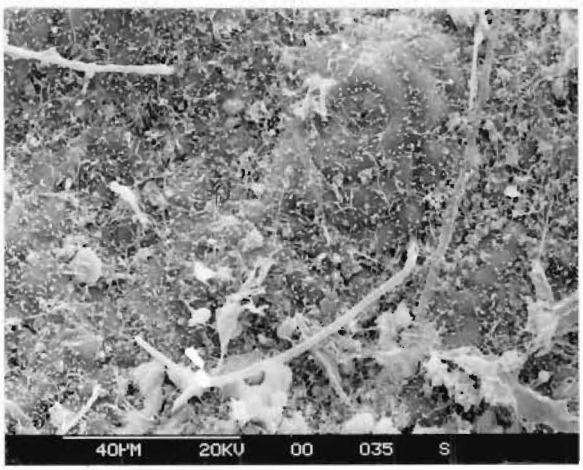
C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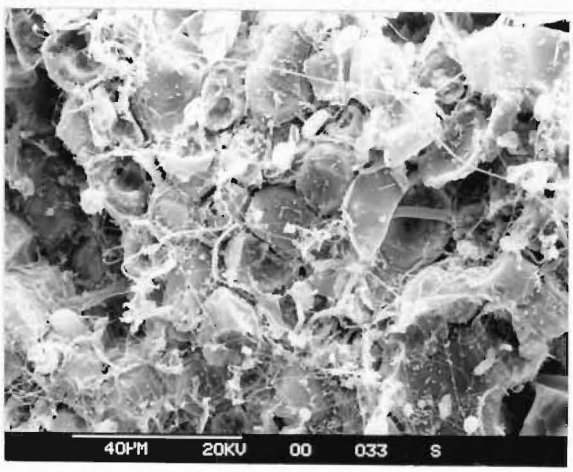
D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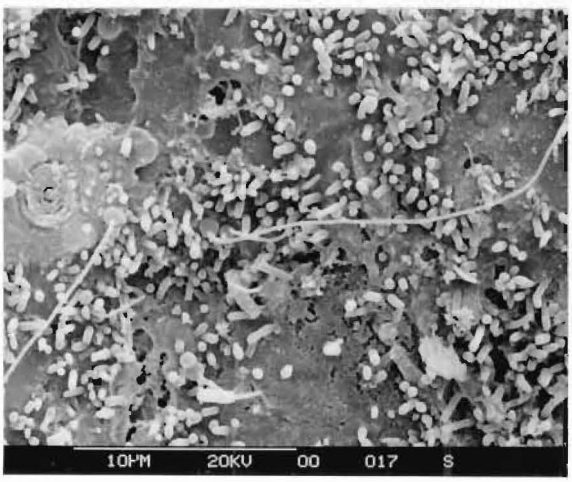
E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F

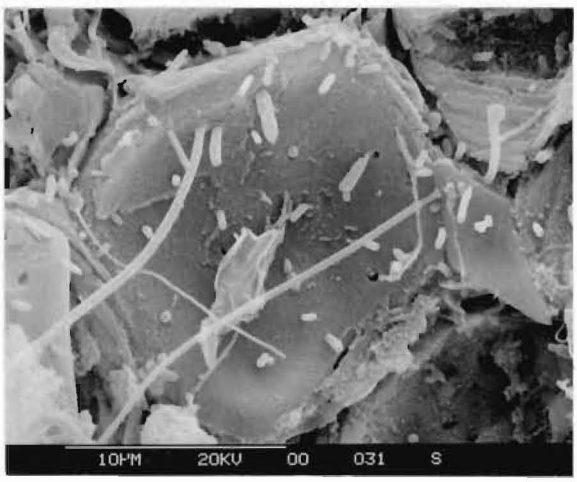
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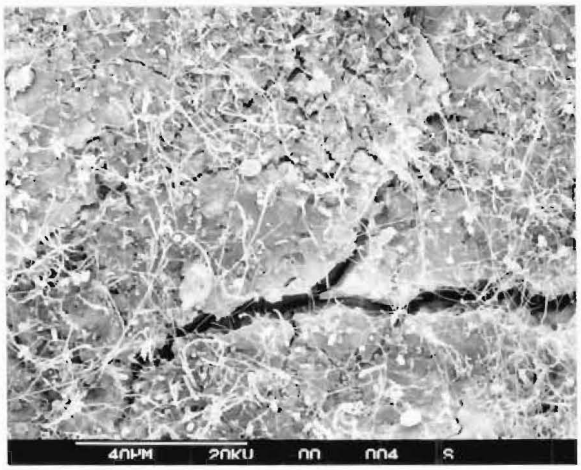
Plate 5.5 The lower surfaces of leaves collected from 7 mm mesh bags after 220 days submersion at site 3, were cover in a thick amorphous layer (A) that seemed to protect the lower epidermis (B) from microbial colonisation. In contrast the upper epidermis was missing, exposing the pallisade cells and leaf veins (C). A similar thick amorphous material interwoven with filamentous organisms (D) was present at site 5. Typically, the lower epidermis (E) was intact, whereas the upper epidermis was typically missing at most sites, exposing the palisade cells.

A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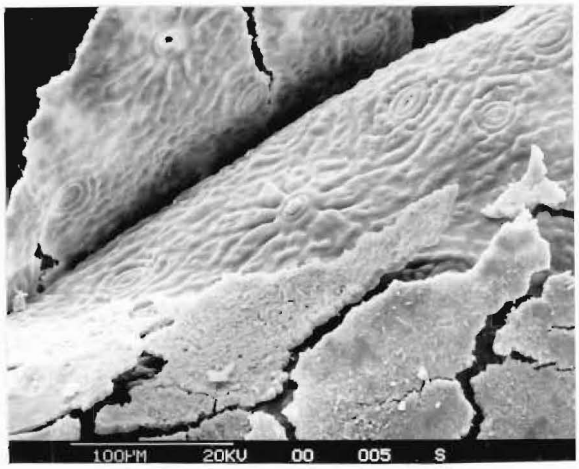
B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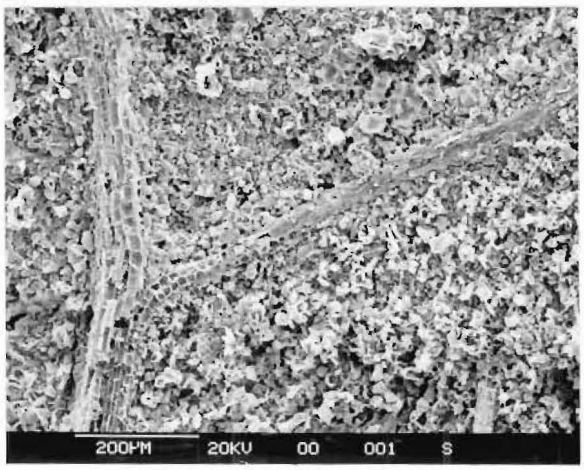
C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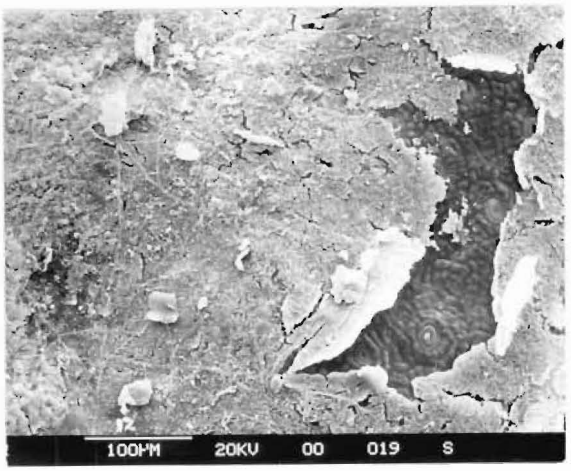
D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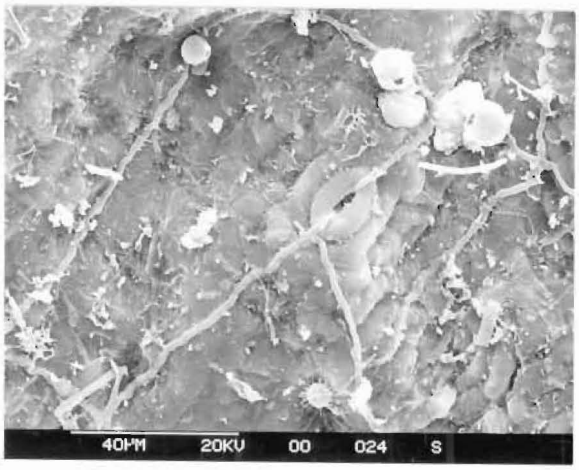
E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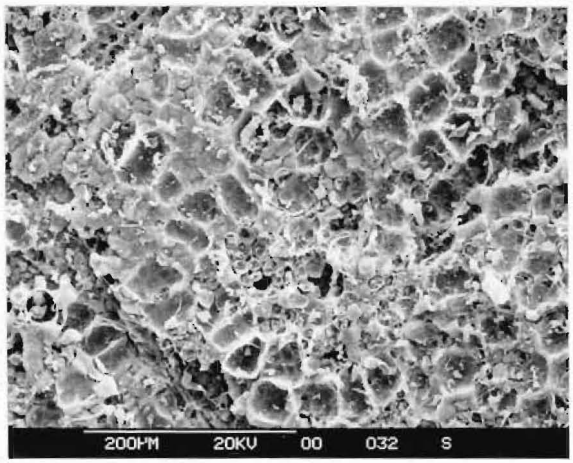
F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than 2 km apart and would have had essentially the same temperature regimes, and temperatures including winter minima at Sites 1, 2, and 4 were close to those reported by Collier (1988) in South Westland. Discharge also seems unlikely to have had an effect and cannot explain differences observed at the two mainstem sites. Furthermore, Site 1 was of similar size and probably discharge, to Collier's (1988) clearwater sites (pers. observations). Finally, differences in breakdown rates were probably not related to pH or other measured chemical variables as these did not differ substantially among sites.

Scanning electron microscopy indicated that various filamentous microorganisms, including actinomycetes and fungi were the predominant colonists of leaves at all sites. Various authors (e.g., Kaushik and Hynes 1971, Suberkropp and Klug 1976, 1981) have suggested that fungal activity is highest during the initial stages of decomposition, but as the amount of internal leaf surface available for colonisation increases through microbial degradation or invertebrate feeding, bacteria may become more important. Like Collier (1988), I found no evidence of a fungal-bacteria succession on the surfaces of leaves, but the upper epidermis appeared to be more susceptible to microbial attack, and the lower surface commonly remained intact much longer.

Suberkropp and Klug (1981) also suggested that humic acids may complex with organic leaf constituents (e.g. proteins) during decomposition, rendering the latter unavailable to many microorganisms, and Collier (1988) considered that such complexing could account for at least some of the low microbial processing of leaves in acid, brown water streams in the South Island. In Stewart Island streams with similar concentrations of dissolved organic carbon (and by implication humic substances), microbial processing of leaves (as indicated by breakdown rates in 0.2 mm mesh tubes) was greater than he found. However, loss rates were comparable to those reported for clear, glacial valley streams with very low DOC concentrations (Collier 1988). Furthermore, microbial decomposition appeared to be slowest at Site 1 which had the lowest DOC concentration. Together, these findings suggest that humic acids had little inhibitory effect on microbial breakdown.

The effects of invertebrate feeding on leaf breakdown were apparent at Sites 3 and 4 after 62 days, and by day 120 significant differences in

the weight of leaf material remaining were found between 0.2 mm and 7 mm mesh bags at all sites. The particularly fast rates of breakdown at Site 1 can probably be attributed to the feeding activities of *Austroperla cyrene* and perhaps to a lesser extent *Zelandobius confusus, Z. furcillatus, Chiltonia rivertonensis,* and *Paraleptamphopus subterraneus.* Similarly, the feeding activities of some of these species, especially *A. cyrene*, and perhaps *Mauiulus luma, Austroclima sepia, Neozephlebia scita,* and *Zephlebia spectabilis,* probably accounted for the faster leaf breakdown rates at Sites 1, 2, and 4 than at Sites 3, 5, and 6. Most of these species have been considered to be collector-browsers (Towns 1979, Anderson 1982, Winterbourn *et al.* 1984) which mainly ingest fine particulate matter, although some like *Z. confusus, Z. furcillatus, A. sepia*, and some *Zephlebia* species are known to feed on wood and leaf material (Cowie 1980, Anderson 1982).

Collier and Winterbourn (1986) recorded particularly fast breakdown rates for willow leaves in two Christchurch streams despite the presence of an invertebrate community comprised almost solely of fine particle feeders and browsers. They suggested that grazing by the snails *Physa acuta* and *Potamopyrgus antipodarum* both physically broke down the leaves, and exposed their internal tissues to microbes. At least some of the collector-browsers found in Stewart Island leaf bags may have had similar effects in addition to acting as opportunistic shredders. Likewise, the greater abundance of some of these species in Stewart Island than in Westland leaf packs, (Collier 1988) probably explains the faster breakdown rates recorded on the island.

In contrast, *Austridotea benhami* appeared to have had a minimal effect on leaf breakdown judging by the very small numbers of individuals found in leaf bags even at sites where they were common. The slow breakdown rates recorded at these sites also supports this contention, as do the results of gut analyses reported in Chapter 4. Thus, even though wood was a frequently observed material in guts, leaves appeared to be consumed rarely, if at all.

In summary, breakdown rates of kamahi leaves on Stewart Island were up to three times faster than rates reported by Collier (1988) in South Westland glacial streams, and some fell into the "fast" category of Peterson and Cummins (1974). However, microbial breakdown rates appeared to be of a similar magnitude to those found in clearwater streams on the

west coast of the South Island (Collier 1988) and suggests that humic acids in Stewart Island stream waters resulted in little inhibition of decomposition. A considerable proportion of the leaf weight losses recorded could be attributed to invertebrate feeding by *Austroperla cyrene* and perhaps a number of "collector-browser" species that can act as facultative shredders.

CHAPTER 6

THE FRESHWATER FISHES OF STEWART ISLAND AND THEIR DISTRIBUTIONS

INTRODUCTION

New Zealand has a small indigenous freshwater fish fauna by overseas standards. Only 27 species were recognised by McDowall (1978), compared with up to 130 in Japan, 70 in Britain (Hopkins and McDowall 1970), and 190 in Australia (Merrick and Schmida 1984).

The New Zealand fauna is highly endemic, (at least at the specific level), is of southern Gondwanan ancestry, and has close ties with southern Australia (McDowall 1987). It is dominated by 13 species in the family Galaxiidae, and 6 species of Eleotridae (bullies). The more widely distributed species tend to have lowland distributions and marine stages in their life histories, whereas more localised species are found mainly in upland waters, and have no marine phase in their life histories (McDowall 1968).

All species feed predominantly on invertebrates although a few of the larger species (*e.g. Anguilla dieffenbachi*, *Galaxias argenteus*) are partly piscivorous.

Since the arrival of Europeans, there appears to have been a significant decline in native fish stocks. For example, observations in Westland in the late 1800s, by explorer Charles Douglas (McDowall 1980) indicated that adults of some of the larger galaxiids were more plentiful then than they are today. Of the giant kokopu (*G. argenteus*) Douglas wrote: " This unholy looking fish is common all over the country wherever a bog hole or dark bush creek exists". Today this species is considered to be rare (McDowall 1978).

Whitebait (young galaxiids) catches are thought to have declined significantly since the arrival of Europeans. However, since the inception of catch records in the 1930s, no significant decline can be distinguished from the available data (McDowall and Eldon 1980). Whitebait runs certainly appear to have been much larger last century than they are today: anecdotal evidence for this is provided by F.C. Clarke (in Main 1988) who described whitebait being caught and used as

manure to cover several acres of a chinaman's garden in Westland, following a very heavy run. Furthermore, it is known that lake whitebait once formed the principal food supply for some central North Island Maori tribes (McDowall 1987). In Lake Taupo, whitebait were so abundant in the early 1900s, that after heavy winds fish were cast up on the beaches in large enough numbers to be used for food (Fletcher 1919 in McDowall 1987). Such large stocks no longer exist.

Today the New Zealand red data book lists the grayling (*Prototroctes oxyrhynchus*) as extinct; the Canterbury mudfish (*Neochanna burrowsius*) as rare, and three other species (black mudfish, *N. diversus*; short jawed kokopu, *Galaxias postvectis*; and giant kokopu, *G. argenteus*) as indeterminate (i.e., status unknown but thought to be rare, vulnerable, or extinct, Williams and Given 1981).

Various factors have probably contributed to the decline in our endemic fish fauna. First, it is clear that most native fishes are now most abundant in unmodified catchments, or directly downstream of forested ones. Large galaxiids (banded kokopu (*G. fasciatus*), giant kokopu, short jawed kokopu, and koaro (*G. brevipinnis*)) show disjunct distribution patterns, and their largest populations occur in regions such as Westland where extensive tracts of virgin forest and wetland still exist (Main 1988). Changes in fish fauna have been associated with changes in land use in some tributaries of the Waikato River, with a decline in diversity being apparent as the amount of indigenous forest cover in the catchment declines (Hanchet 1990). Loss of habitat associated with forest clearance was also implicated by Main (1988) as an important contributor to the decline of the large galaxiids. Unfortunately, reduction of forest cover has been dramatic: from an estimated 75 percent in A.D. 700, to only 26 percent today (Newsome 1987).

Swamp drainage and development, and reclamation of estuaries are also considered to be major contributors to the decline of adult galaxiid stocks, and hence the New Zealand whitebait fishery (McDowall 1975) . Swamp lands, coastal creeks, and drains are important fish habitats, and estuarine vegetation is essential for successful spawning of at least some galaxiids. Unfortunately, there have been major losses of wetland habitats, and by 1976, it was estimated that about 263 000 ha of wetland

had been drained (Burns 1982). Furthermore, it is probable that less than 10 percent of the wetlands remaining in 1981 were unmodified (Davis 1987).

Developments often associated with forest clearance or swamp drainage, including the insertion of culverts and flood gates, channelisation of rivers, and construction of impoundments have also had detrimental, although usually local, effects on fish stocks and habitat.

The introduction of trout has also been implicated in the decline of native fish stocks. In many central North Island lakes the presence of trout has led to the virtual elimination of whitebait (McDowall 1987). More recently, the disappearance of the dwarf inanga (*G. gracilis*) from a small North Island lake was attributed to the introduction of rainbow trout (*Onchorhynchus mykis*) (Fish 1966). Various authors (McDowall 1968, 1987, Cadwallader 1975, Main 1988) have suggested that trout have competitively displaced some galaxiids from mainstem habitats into headwaters, tributaries, and marginal areas, presumeably with detrimental effects on stocks. In South Westland, adult trout were not recorded in association with giant, banded, or short jawed kokopu, or with adult koaro (Taylor 1988).

Exploitation of lotic whitebait and eel stocks must also have contributed to the decline of some species. In Westland, Main (1988) estimated that the mean annual whitebait catches in Westland between 1951 and 1973 represented a mean annual mortality of 242 million fish. This must have had a significant effect on the abundance of riverine stocks of the five galaxiid species (koaro, inanga (*G. maculatus*), banded, giant, and short jawed kokopu) that make up the whitebait catch.

It is very difficult to separate the effects of different disturbances on members of the biota as they often occurred concurrently, and possible impacts on the native fauna received little consideration at the time. Furthermore, even today our understanding of the basic biology of many native fish species is so poor that debate becomes largely conjectural and anecdotal. This poses problems when considering the management and restoration of native fish stocks. There is a very real need for detailed studies of native fish ecology in pristine, or at least largely unmodified, New Zealand environments.

Few if any sizable catchments on the two main islands are totally free from human disturbances. Large tracts of lowland forest are mainly restricted to Westland, Fiordland and parts of Southland, and even there many are affected by farming, forestry, and mining. Fiordland is relatively untouched, but its glacial topography and extremely high rainfall (up to 10,000 mm per annum, Duncan 1987) mean that many streams there provide more extreme physical environments than those in most other parts of New Zealand. This aside, trout and/or salmon are present in almost every catchment of any size in the South Island, including Fiordland (Hinds 1976, McDowall 1978), and most of the North Island as well. Finally, where large, healthy, whitebait populations do exist, they are usually heavily exploited by fishermen.

On Stewart Island, relatively pristine environmental conditions appear to exist. Trout are absent, or present in very low numbers; lowland forest is intact; and unmodified catchments abound. In view of this, it is somewhat surprisingly that the fish fauna is virtually unexplored. McDowall (1987) only recorded four fish species (*Galaxias maculatus*, *G. fasciatus*, *G. brevipinnis*, and *Gobiomorphus huttoni*) although he gave a distributional record for a fifth (*Galaxias argenteus* in an earlier account (McDowall 1978).

The objectives of this part of my study were:

(i) To define the fish stocks present;

(ii) To record distributional patterns, and identify the principal habitats utilized by fish, especially in the mainstems of rivers.

I decided to emphasize the latter objective, because (as already noted), it is thought that trout have competitively displaced native fish from these habitats on the main islands of New Zealand.

METHODS

Sampling techniques were adapted from methods used by Fisheries Research Division personnel when making surveys in South Westland (Main *et al.* 1985, Taylor and Main 1987). This was done to allow direct comparisons to be made with the results of their surveys.

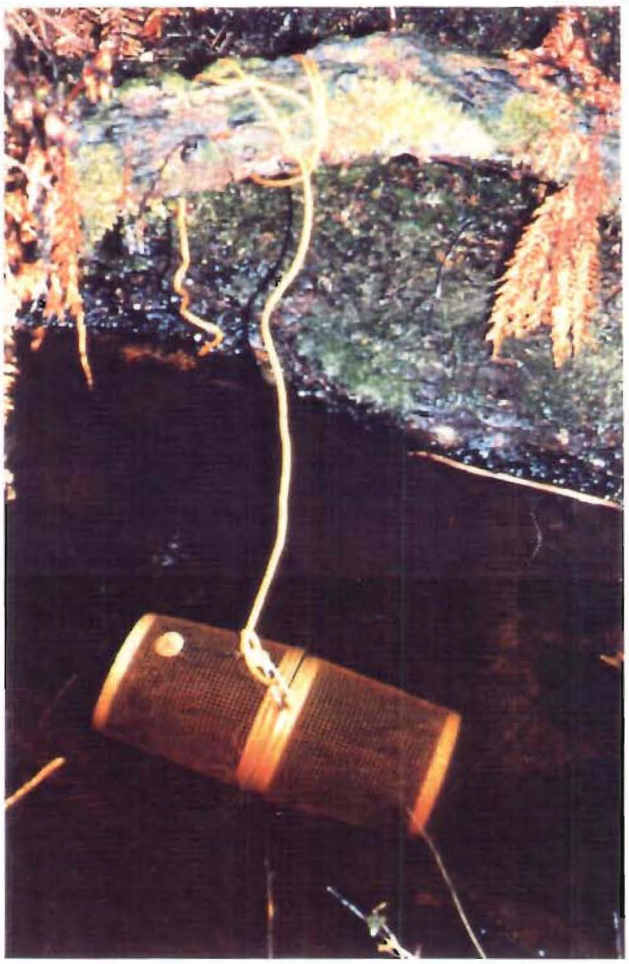
Streams were surveyed using a combination of baited Gee minnow traps (Plate 6.1a), mini fyke net (mesh size 5 mm, Plate 6.1C), and commercial grade fyke nets (mesh size 10 mm Plate 6.1B), a push seine net, and a

Plate 6.1A. A Gee minnow trap set in a tributary of Maori River.

Plate 6.1B. Emptying the large double fyke net in the Lower Rakeahua River.

Plate 6.1C. Mini fyke net set in the swamp in the lower Rakeahua Valley.

A



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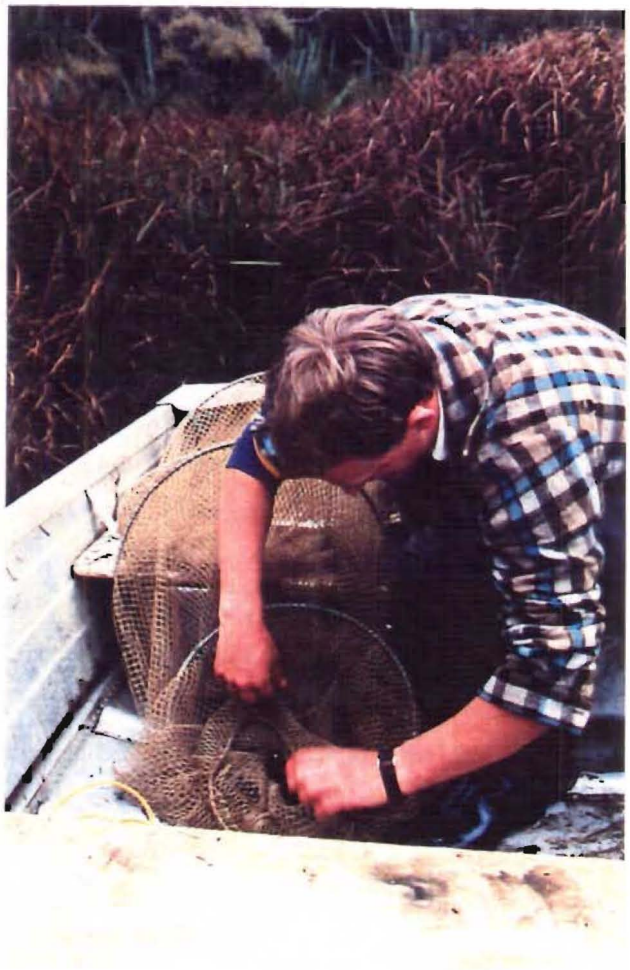

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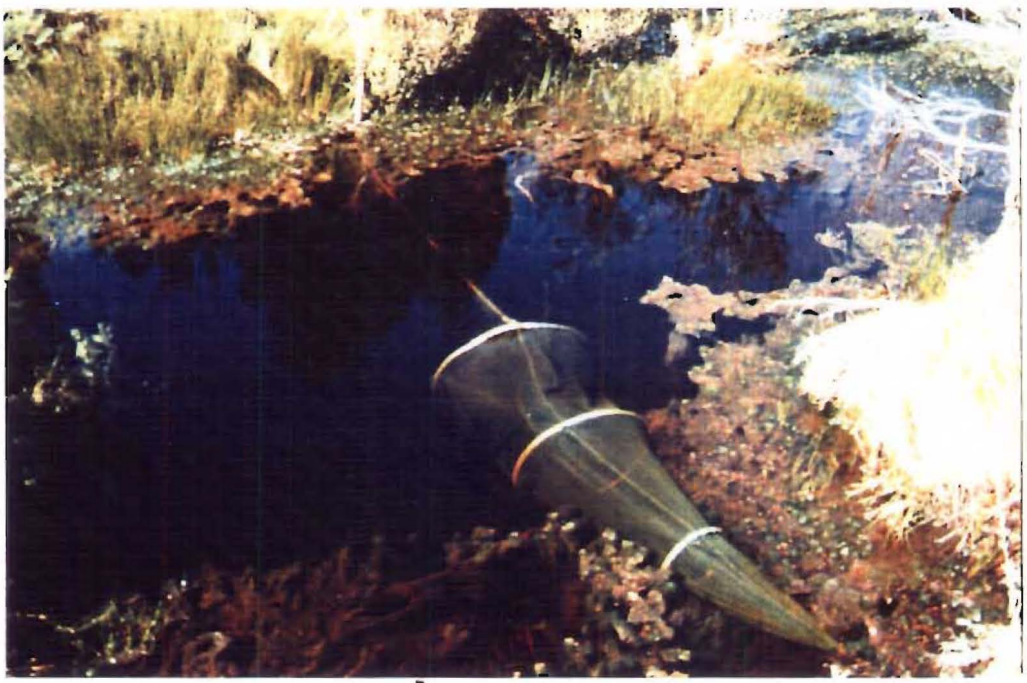

wire whitebait net, supplemented with observations.

Descriptions of Gee minnow traps and both types of fyke net are given by Main *et al.* (1985) and Main (1988). Gee minnow traps were usually baited with either a mixture of salmon feed pellets and Marmite, or Marmite alone. Peanut butter, offal, meat, deer pellets, and bread were also tried in the early stages of the study, but they were less effective.

Like Main *et al.* (1985), I assumed that fish caught by minnow traps were resident in the immediate area, although a few fish were probably attracted from further away by the bait. In contrast, fyke nets are passive traps that rely on fish swimming along the wing barrier and into the net. A disadvantage of fyke nets (as noted by Main *et al.* 1985), is that when eels are caught, it is often necessary to examine their stomach contents to find the rest of the catch! I did this early in the study but soon abandoned the practice as few eels were found, to contain fish, and those that were found were often difficult to positively identify.

The hand-held, push-seine net (push net) comprised a 1.5 m wide apron of mosquito netting (mesh size 0.5 mm) slung between two bamboo poles, and weighted at the lower end with a heavy chain. Generally it was worked by two people (Plate 6.2A). One person would hold the net downstream, angled so that the bottom half of the apron/net lay on the stream bed, while the other person rapidly turned over the larger stones and cobbles in front of the net. Any fish pushed on to the apron were scooped up.

The wire whitebait net consisted of a framed box (height 33.5 cm, length 76 cm, depth 46 cm) enclosed on all sides except the base by 3 mm^2 mesh, wire netting. It was used in a similar fashion to the push net, but was often operated by one person.

The pushnet was most effective in shallow (10-30 cm) riffles, whereas the whitebait net was better in deeper, faster flowing rapids.

Some fish were caught accidentally in invertebrate samples.

Both intensive and spot sampling techniques were used to obtain distributional data. Spot sampling involved the use of one or two minnow traps and/or mini fyke nets supplemented with observations and sometimes pushnetting in one or two riffles. Intensive sampling involved setting two commercial fykes, three mini fykes, and six minnow traps within a 200 to 1000 m stretch of river, and leaving them overnight. Nets and traps were generally set in pools, ponds, backwaters and slugs (slow runs), and

Plate 6.2A. A riffle being worked with the push net.

Plate 6.2B. Typical *G. fasciatus* habitat in the Maori River. Note the large substrate, overhanging banks, instream debris and foam on the water surface.

Plate 6.2C. Typical giant kokopu habitat in "Hut Stream" (lower Rakeahua River). Note overhanging vegetation, manuka trees, undercut banks and instream debris.

A

B

C

were emptied the following day when riffles, rapids and shallow runs were worked with the pushnet or whitebait net.

Fish were identified in the field and released at capture locations. Only when there was some doubt about the identity of fish were, specimens retained and preserved in 10 percent formalin. These specimens were more closely examined at the University of Canterbury, and their identities confirmed by R.M. McDowall and G.A. Eldon (Fisheries Research Division, Christchurch).

Physicochemical and biological descriptors of sites were recorded on Freshwater Data Base forms (McDowall and Richardson 1983, Table 6.1), and water samples were collected from most sites for analysis at the University of Canterbury (see Chapter 3).

Because sampling effort and the length of reaches varied from site to site, truly quantitative data could not be collected. Instead, abundance was indicated by using an abundant > common > occasional > rare index, where rare = 1 to 2 fish / 100 m, occasional = 3 to 5 fish / 100 m, common = 6 to 10 fish / 100 m, and abundant = 11+ fish / 100 m. Throughout this chapter, references to species' abundances relate to these measures.

On most occasions, rivers were surveyed on foot. However, an aluminium dinghy was used to set nets and traps in the deeper, lower reaches of the Rakeahua River.

The Rakeahua and Maori River valleys were sampled intensively almost along their entire lengths. Most of this work was done in March 1989, but some sites were sampled in May, August and November, 1989. In total, 19 sites in the Rakeahua Valley (Fig. 6.01) and 12 reaches in the Maori River Valley (Fig. 6.02) were sampled. Intensive sampling data were supplemented with a number of spot collections and observations at various times during the year.

Streams on the northern tramping circuit (Fig. 6.03) were spot sampled in January 1988, principally by Richard Allibone (University of Otago). However, Big Glory Stream (November 1987), Duck Creek (March 1989), Christmas Village Stream (November 1989), Mt. Anglem Tarn Stream (November 1989) and Murray River (November 1989) were sampled intensively (full set of nets and traps). Furthermore, Freshwater Landing

Table 6.1. A freshwater data base form, as used in Stewart Island fish surveys.

FRESHWATER FISH DATABASE FORM	PLEASE RETURN FORM TO: MAFFish Fisheries Research Centre P.O. Box 951 ROTORUA	10323
Date	River/Lake system	Catchment number
Time	Sampling locality	
Observer	Access	Altitude (m)
Organisation	NZMS1 NZMS260 Map no. Coords.	Inland dist. (km)
Fishing method	Area fished (m²) or no. nets used / Permanent water yes/no/unknown	Tidal water yes/no/unknown

HABITAT DATA

Water	Colour blue/green/tea/uncoloured/other:				Clarity clear/milky/dirty	Temp.	pH
	Average width (m)		Average depth (m)		Maximum depth (m)	Conductivity	
Habitat type (%)	Still	Backwater	Pool	Run	Riffle	Rapid	Cascade
Substrate type (%)	Mud	Sand	Fine gravel	Coarse gravel	Cobble	Boulder	Bedrock
Fish cover (%)	Substrate	Weed algae	Instream debris	Bank veg.	Undercut banks	O/head shade	Other
Catchment vegetation (%)	Native forest	Exotic forest	Horti-culture	Urban zone	Scrub	Pastoral	Other
Riparian vegetation (%)	Native forest	Exotic forest	Grass tussock	Exposed bed	Scrub willow	Raupo flax	Other
Type of river/stm/lake							Photo no.
Water level low/normal/high/unknown			Downstream blockage yes/no/unknown			Pollution nil/low/moderate/high	
Bottom fauna abundance low/moderate/high/unknown			Predominant species group mayflies/caddis/snails/other:				

FISH DATA

Species and life stage	Abundance*	Length data (see reverse)	Comments/capture location

General comments about site or fish

*Use abundant, common, occasional, rare or numbers observed

These sections must be filled in

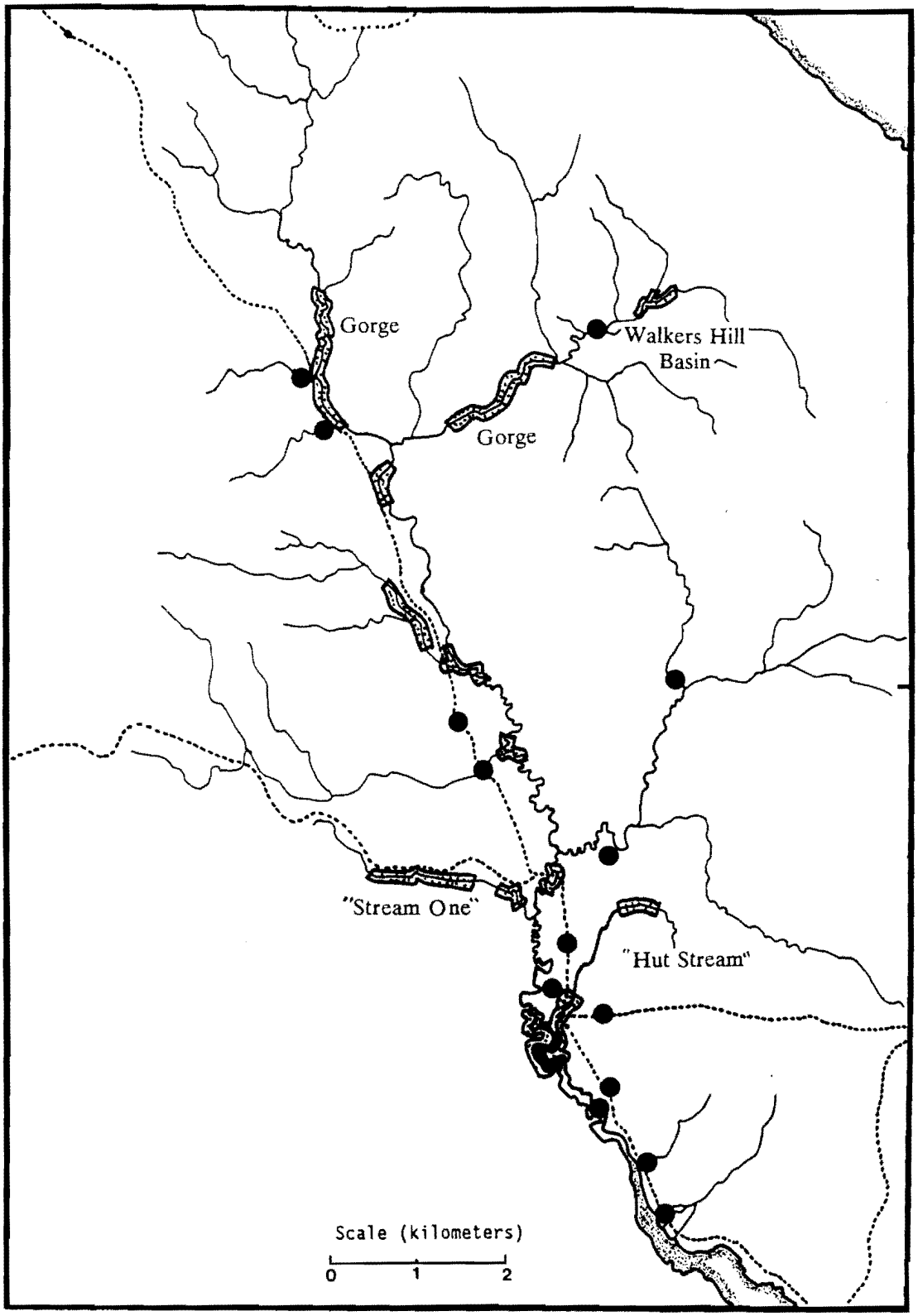

Fig. 6.01. Fish survey sites in the Rakeahua River valley (March 1989 to December 1989). ● = spot samples, ▨ = intensively sampled reach.

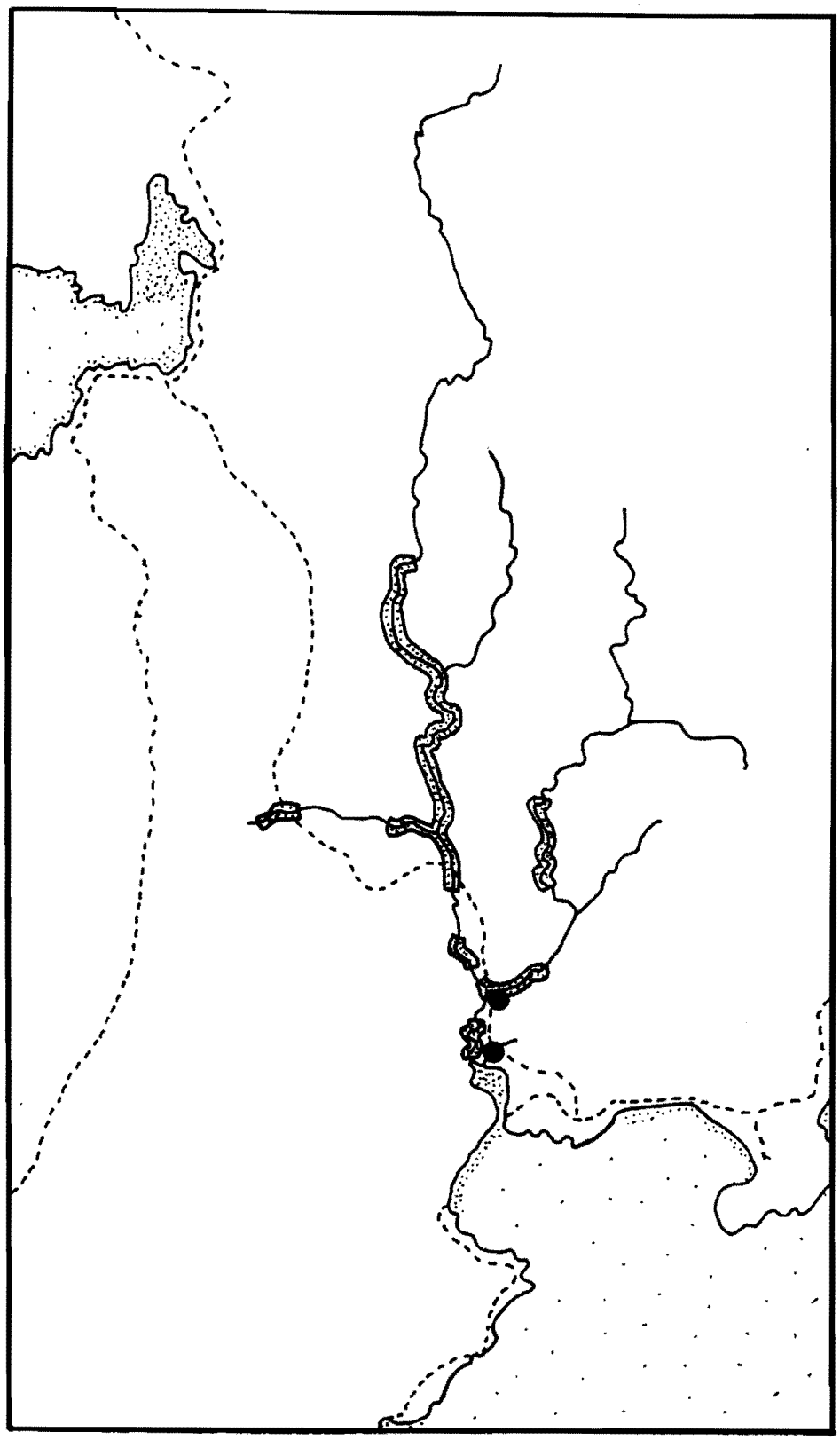

Fig. 6.02. Fish survey sites in the Maori River valley (March 1989 to December 1989). ● = spot samples, ▭ = intensively sampled reach.

(Freshwater River) was trapped continuously with two Gee Minnow Traps for 24 hours in January 1988, and with six traps over a 48 hour period in March 1989.

RESULTS

Fish stocks

Twelve species of native fish and one introduced salmonid (*Oncorhynchus tshawyscha*) were collected from Stewart Island (Table 6.2). Six had not been recorded from the island previously, and the suspected occurrence of both species of eel was confirmed. All fish except the common river galaxiid (*Galaxias vulgaris*) are diadromous, i.e., they migrate between fresh and salt water. Distributional and relative abundance data for each catchment are summarised in Table 6.3.

Distribution and habitat descriptions

Banded kokopu (*Galaxias fasciatus*)

The banded kokopu was the most commonly caught, and most widespread species. It was taken from 13 catchments, and appears to be present throughout the northern half of Stewart Island (Fig. 6.04, Table 6.3). *G. fasciatus* was taken from a variety of streams ranging from clear, circumneutral pH waters to acidic brown waters. Of the 24 streams containing *G. fasciatus*, 25% were between 2.5 and 5.0 m wide and 50% were over 5 m wide.

In the middle to upper reaches of the Rakeahua and Maori Rivers (Figs 6.05 & 6.06, respectively), banded kokopu were more abundant in mainstem habitats than in smaller side branches. In the lower reaches of both rivers, few fish were taken from the mainstems, but they were common in the middle reaches of tributaries.

Backwaters (Plate 6.2B) appeared to be the preferred habitats of *G. fasciatus*, although fish were also taken frequently from pools and slugs (slow runs) (Fig. 6.07). Only a few juvenile fish were collected from riffles, and no fish were taken from rapids. Few stills and ponds were sampled, although 24 adult banded kokopu were observed in a small pond (10 by 5 m; 1 m deep), at the confluence of the Maori River and its main

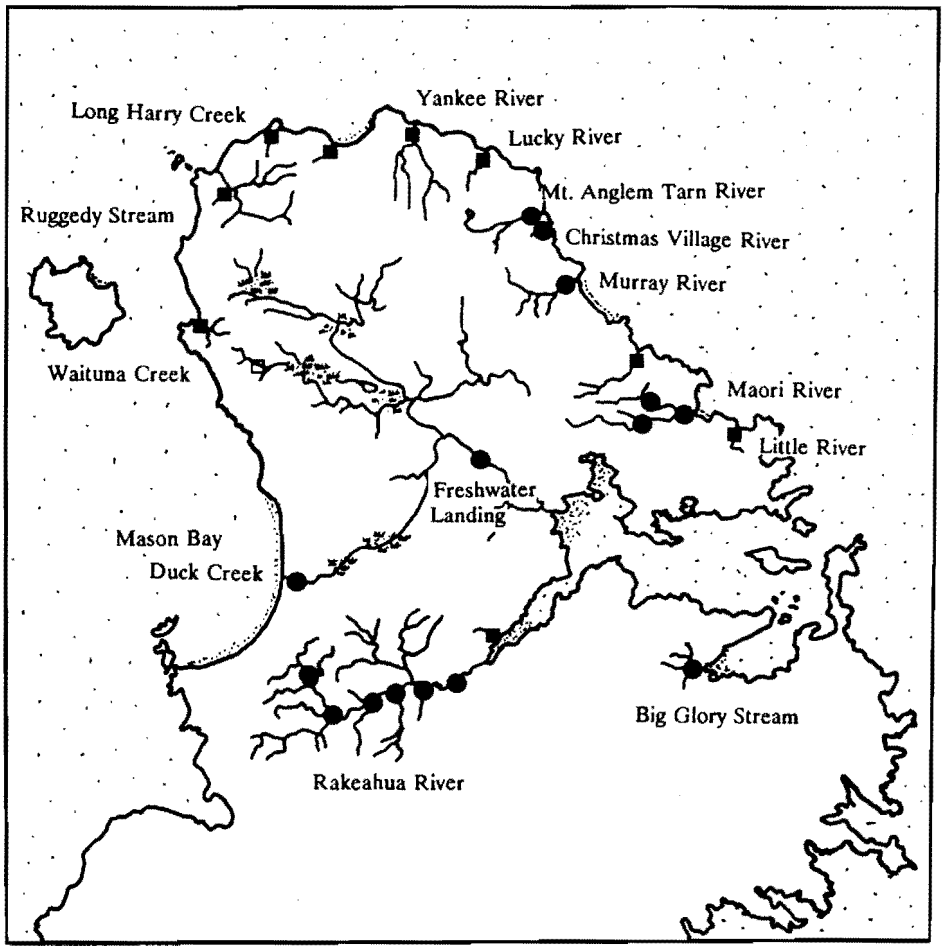

Fig. 6.03. Fish survey sites in streams of northern Stewart Island sampled between August 1987 and December 1989. = spot sample, = intensive sample.

Table 6.2. The freshwater fishes collected from Stewart Island between August 1987 and December 1989.

Family:	Species:	Common name:
Galaxiidae:	*Galaxias argenteus*	Giant Kokopu
	Galaxias fasciatus	Banded Kokopu
	Galaxias brevipinnis	Koaro
	Galaxias maculatus	Inunga
	Galaxias vulgaris	Common river galaxiid
Retropinnadae:	*Retropinna retropinna*	Common Smelt
Eleotridae:	*Gobiomorphus huttoni*	Red finned Bully
	Gobiomorphus gobioides	Giant Bully
Tripterygiidae:	*Tripterygion nigripenne*	Cockabully
Anguillidae:	*Anguilla dieffenbachi*	Long finned eel
	Anguilla australis	Short finned eel
Geotriidae:	*Geotria australis*	Lamprey
Salmonidae:	*Oncorhynchus tshawytscha*	Quinnat salmon

Table 6.3. Localities and relative abundance of all fish species collected from Stewart Island between August 1987 and December 1989 (* = rare, ** = occasional, *** = common, **** = abundant).

	Galaxias argenteus	*Galaxias fasciatus*	*Galaxias vulgaris*	*Galaxias maculatus*	*Galaxias brevipinnis*	*Gobiomorphus huttoni*	*Gobiomorphus gobioides*	*Anguilla dieffenbachi*	*Anguilla australis*	*Retropinna retropinna*	*Geotria australis*	*Oncorhynchus tshawytscha*	*Tripterygeon nigripenne*
Rakeahua	****	****	****	****	-	****	-	**	*	**	-	*	*
Maori River	**	****	-	*	****	*	-	**	-	-	*	-	*
Murray River	-	**	-	****	****	*	-	**	-	-	-	-	****
Mt.Anglem Tarn	-	**	-	-	****	-	-	**	-	-	-	-	-
Old Xmas Village	-	*	-	-	***	-	-	-	-	-	-	-	-
Yankee River	-	p	-	-	p	p	-	-	-	-	-	-	-
Duck Creek	rare p	**	****	***	-	**	-	**	-	*	-	-	-
F/W Landing	p	-	-	****	-	***	*	**	-	p	-	-	-
Big Glory Stream	-	**	-	****	-	***	-	**	-	-	-	-	-
Robertson River	-	-	p	-	-	-	-	-	-	-	-	-	-
Lucky River	-	p	-	-	p	-	-	-	-	-	-	-	-
Long Harry	-	p	-	-	p	-	-	-	-	-	-	-	-
East Ruggedy	-	p	-	-	-	-	-	-	-	-	-	-	-
Waituna Bay	-	-	-	-	-	***	-	-	-	-	-	-	-
Little River	-	-	-	****	-	-	-	-	-	-	-	-	-

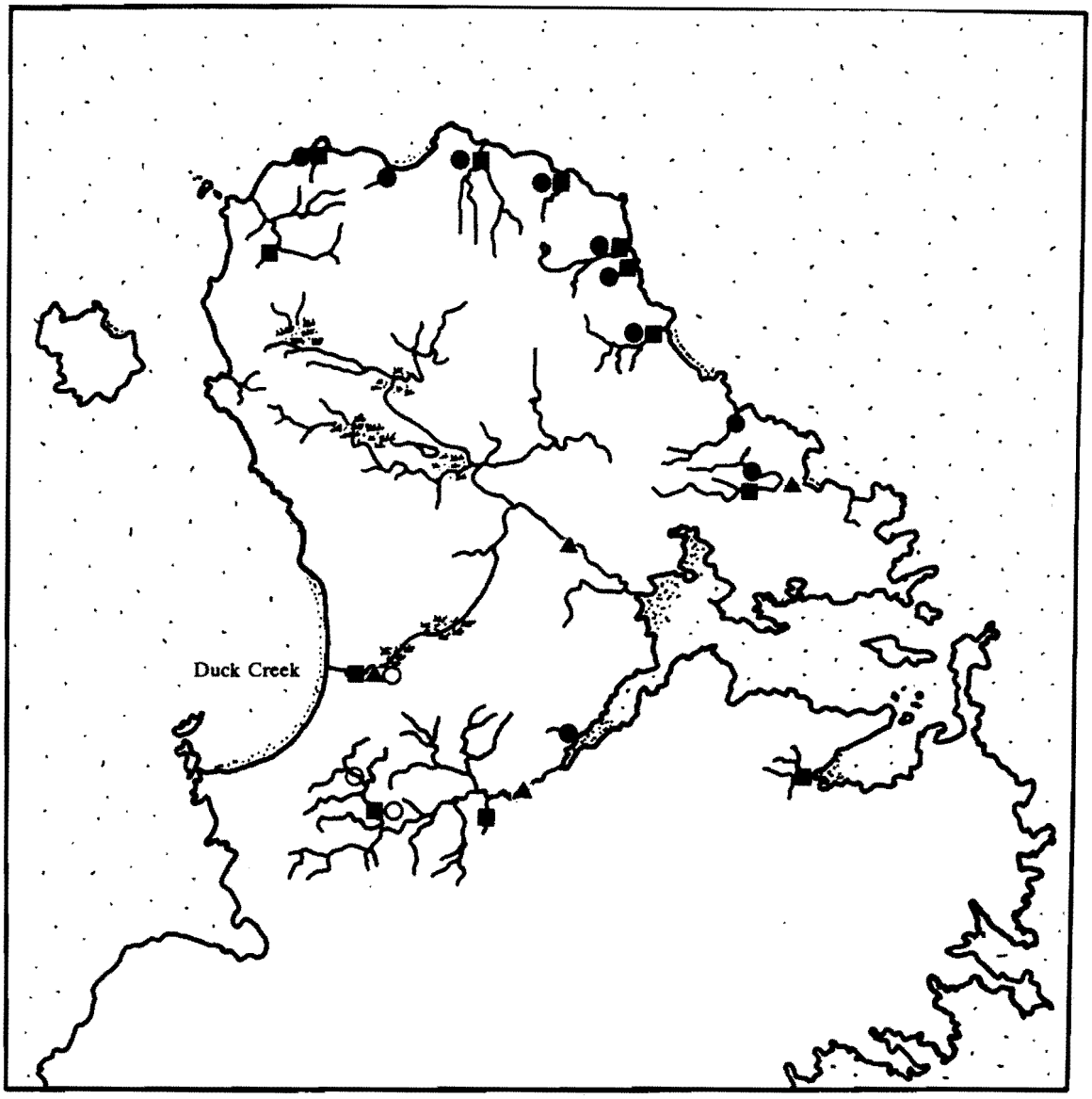

Fig. 6.04. Geographical distribution of *G. fasciatus* (■), *G. argenteus* (▲), *G. brevipinnis* (●), and *G. vulgaris* (○) in northern Stewart Island.

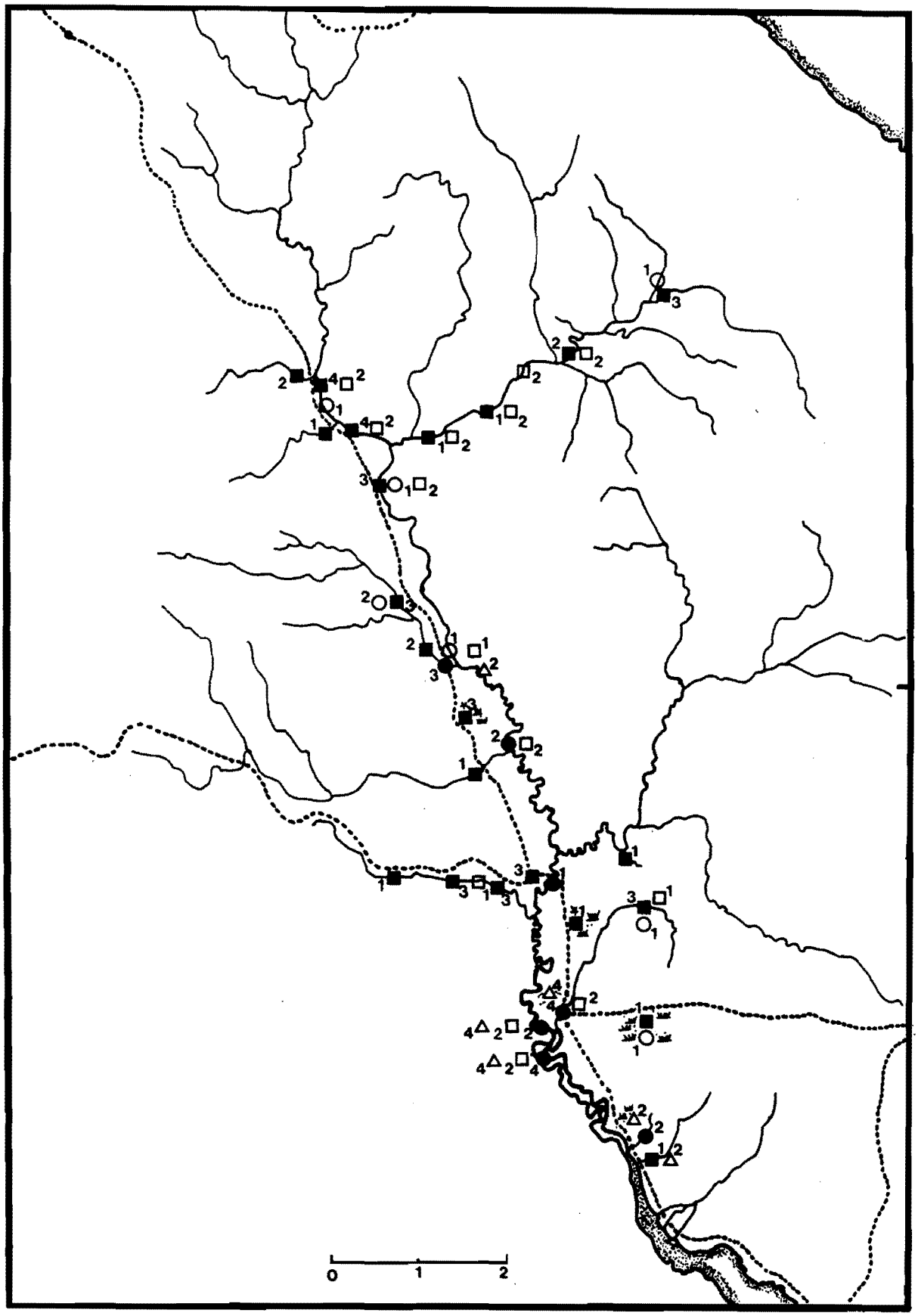

Fig. 6.05. Distribution of *G. fasciatus* (■), *G. argenteus* (adult and juvenile fish, (●)), juvenile *G. argenteus* (○), *G. maculatus* (△), and *A. dieffenbachi* (□) in the Rakeahua River valley. 1 = rare, 2 = occasional, 3 = common, and 4 = abundant.

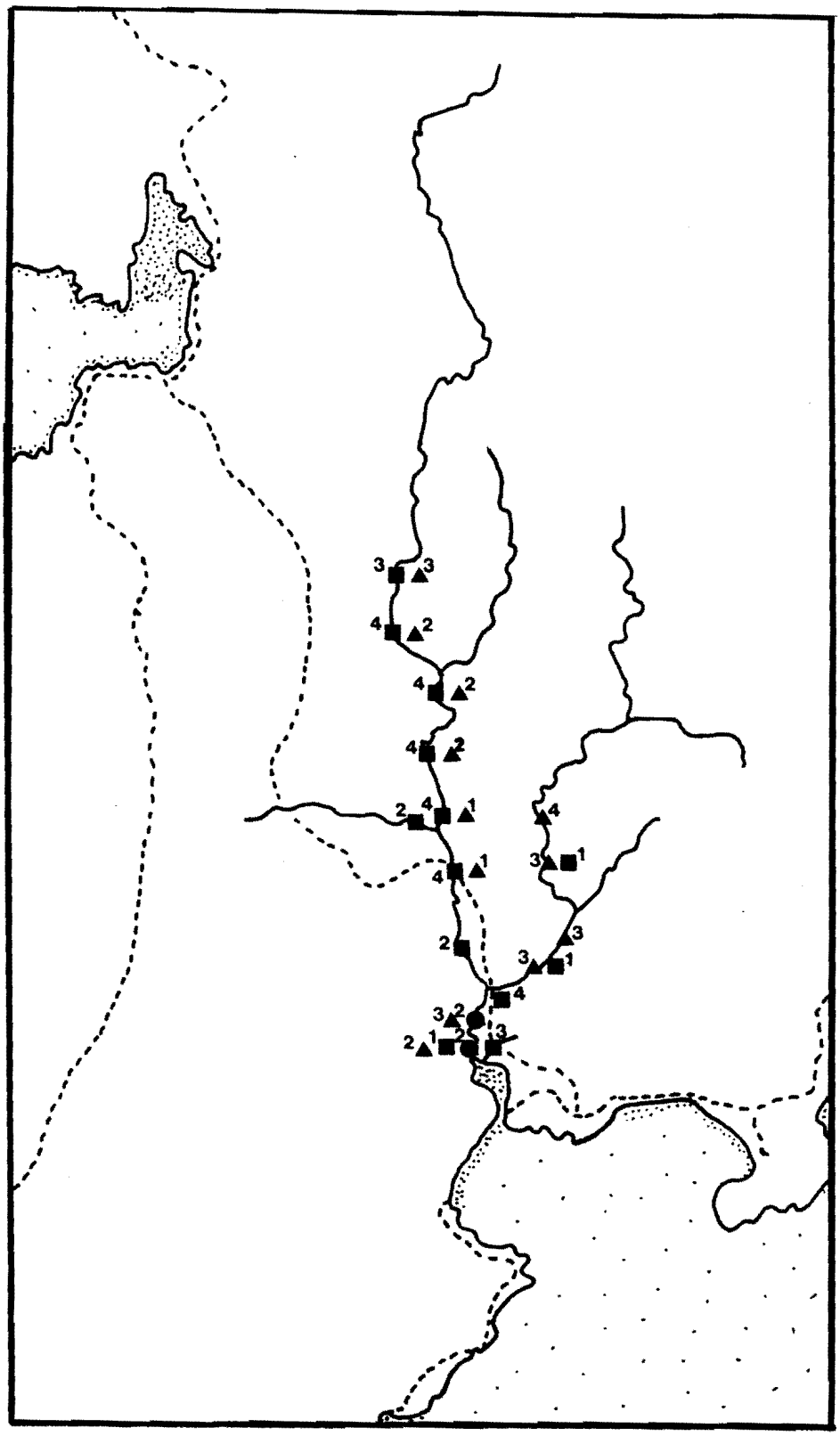

Fig. 6.06. Distributions of *G. fasciatus* (■), *G. argenteus* (●), and *G. brevipinnis* (▲) in the Maori River. 1 = rare, 2 = occasional, 3 = common, and 4 = abundant.

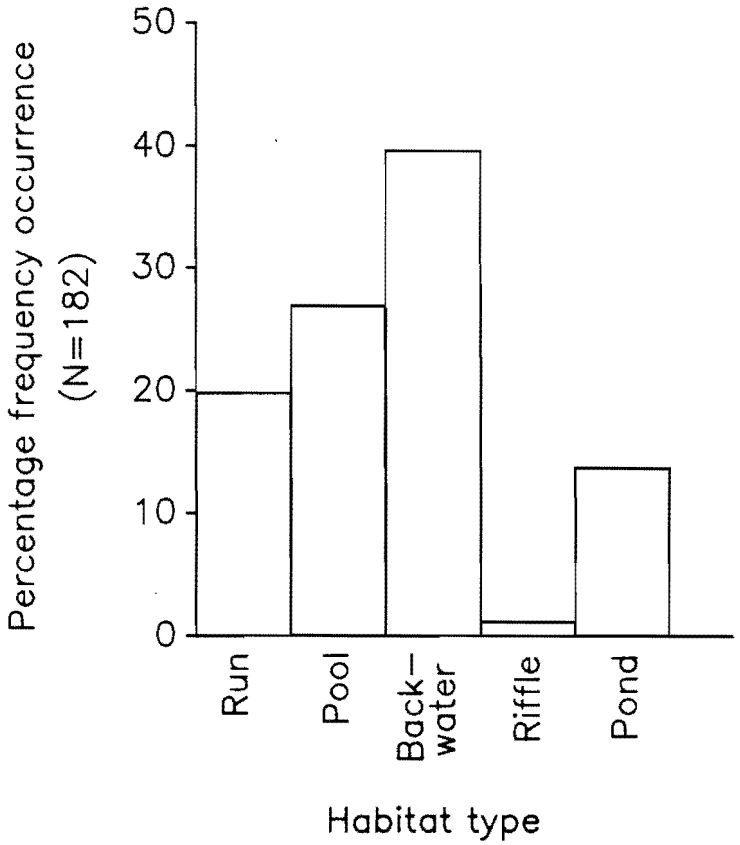

Fig. 6.07. Frequency of occurrence of *G. fasciatus* in various habitat types (n = 182).

tributary, in the lower valley. More typically, between five and ten fish were taken from pools or backwaters along the mainstem of the Rakeahua and Maori Rivers. My general observations indicate that backwaters were commonly utilised in mainstem reaches, whereas pools and slugs were more common habitats in smaller tributaries, and step/stair streams.

A wide range of cover types were utilised by fish, and no preference for a particular cover type was evident. In many cases the only cover available was that offered by bed materials, tannin stained water, and/or the white foam floating on the surface. Observations made at night on the Maori River suggest that cobbles and boulders are as important as overhanging banks, overhanging vegetation and instream logs, as cover.

Almost no overlap was recorded between the distributions of banded kokopu and giant kokopu in either the Maori or Rakeahua Rivers. The only overlap observed, was between juvenile giant kokopu (< 10 cm long) and banded kokopu in the Rakeahua River (Fig. 6.08), and three banded kokopu taken from the same reaches as adult giant kokopu in the lower Maori River (Fig. 6.09). It may be significant that giant kokopu were apparently less abundant in Maori River than in the Rakeahua River.

Giant kokopu (*Galaxias argenteus*)

Although only collected from four catchments, abundant stocks of giant kokopu exist on Stewart Island (Fig. 6.04, Table. 6.3). Large numbers of fish were trapped in the Rakeahua River. On one occasion, eight fish were collected from a single, double fyke net in the mainstem, and over 20 fish were observed in a 300-400 m stretch of "Hut Stream" (Plate 6.2C) in March and in November. These counts were probably underestimates, as waters over 1 m deep, and stretches clogged with debris could not be searched.

In the Rakeahua and Maori Rivers (Figs 6.05 & 6.06, respectively), adult fish were collected from the mainstem and also from lower reaches of tributaries of the former. Subadult fish (those < 10 cm long) were collected throughout the valley from headwaters to tidal reaches (Fig. 6.05). Giant kokopu were common in pools, backwaters and slugs, and a few were collected from stills and runs. Some fish were also taken from slugs and ponds within swampy ground on the Rakeahua flood plain. No fish were seen in, or collected from, riffles or rapids. In the lower Rakeahua, most fish were associated with the predominantly sandy and muddy substrata, but in Maori River, the stream bed comprised a mixture

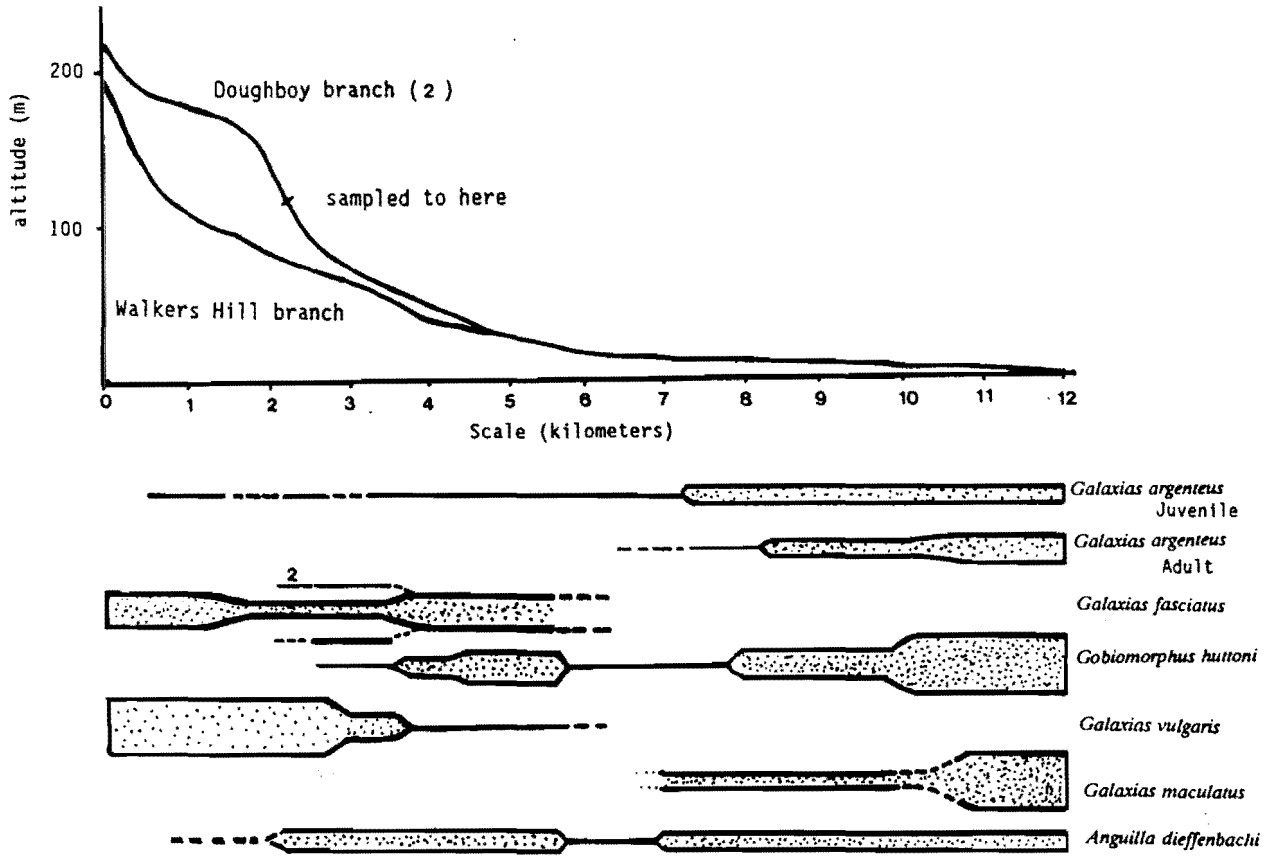

Fig. 6.08. Relative abundance of fishes plotted against longitudinal stream gradient in the Rakeahua River.— = rare, = occasional, = common, = abundant.

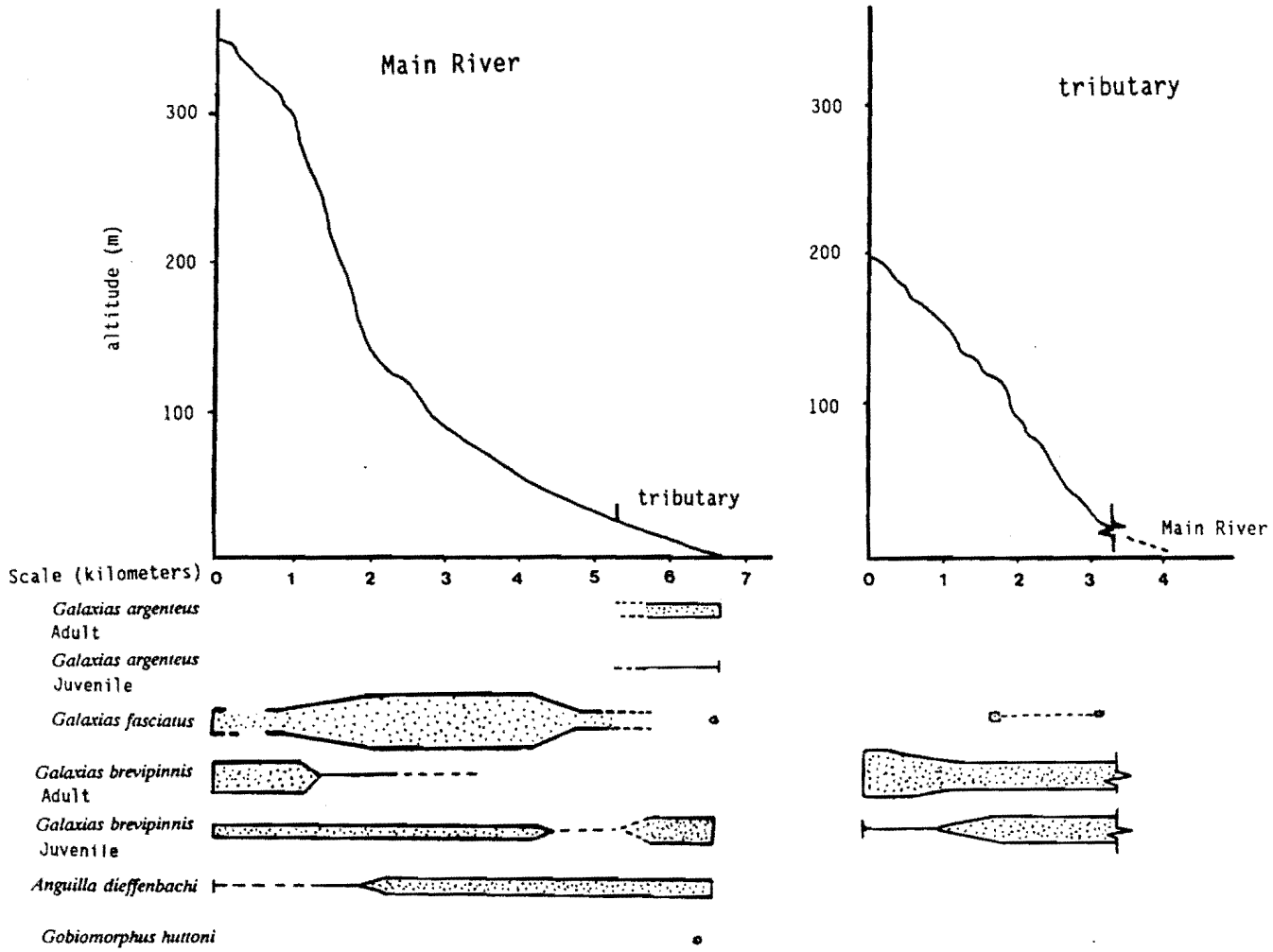

Fig. 6.09. Relative abundance of fishes plotted against longitudinal stream gradient in the Maori River.— = rare, = occasional, = common, = abundant.

of sand, gravels and cobbles. In both systems, large woody debris was usually abundant in giant kokopu habitat and provided cover for fish.

Groups of fish including adults, subadults and whitebait were seen feeding in tributaries of the Rakeahua River at two different sites. In a small pool (1 m^3), one large adult, three subadults and a few whitebait occurred together, at least during the day. I was able to induce them to feed without difficulty, and most of the time the adult giant kokopu allowed the other fish to feed. Only when large prey items were dropped into the water did it chase the others off and feed itself. At another site, fish in a mixed age population were seen feeding during the day, without inducement. At this site, (a sluggish run), fish were more spread out than in the small pool: the adult fish occupied the upper part of the run and the smaller fish were about 4 m downstream of them.

Koaro (*Galaxias brevipinnis*)

Koaro were recorded in nine catchments, and were the second most common species collected (Fig. 6.04). Unlike banded kokopu, koaro appeared to be restricted to east coast streams, north of Paterson Inlet. Consequently, koaro were recorded only in circumneutral to slightly acidic (pH 6.3 to 7.2, mean 6.8), clear to pale brown waters (DOC 5.4 to 11.7 g m^{-3}) with moderately high conductivity (11 to 24 $mS.cm^{-1}$), and alkalinity in the range 6 to 24 $g.m^{-3}$ $CaCO_3$.

Koaro were common in riffles, rapids, runs and pools, and were less frequently seen in backwaters. Pools and runs were more common habitats in reaches where banded kokopu were rarer. In the meandering lower reaches of Maori River only small juvenile fish (<10 cm) were collected (Fig. 6.09). Larger adult fish (>10 cm) were found further upstream where the channel gradient was higher (Fig. 6.09). In contrast, in the shorter, steeper, Mt Anglem Tarn and Christmas Rivers, large adult fish (up to 215 mm long) were collected from the river mouth in estuarine conditions.

Common river galaxiid (*Galaxias vulgaris*)

The common river galaxiid was collected from three river systems including Robertson River (not shown on Fig. 6.04, but see Fig. 2.1, Chapter 2). The specific identity of Rakeahua River fish, which closely resemble *G. brevipinnis*, was confirmed electrophoretically by Richard

Allibone, University of Otago.

G. vulgaris was collected from riffles, rapids and shallow runs. Few individuals were seen in, or collected from pools. Their preferred habitat appeared to be shallow (about 10 cm deep) riffles made up of small, loosely packed gravels and cobbles with very little moss cover.

G. vulgaris was recorded from the middle and upper reaches of the Rakeahua River, and was most abundant from the downstream end of the Walkers Hill Basin to the head waters (Figs 6.08, 6.10). Typically, three to five fish were taken from short (5 m long) riffles.

Red finned bully (*Gobiomorphus huttoni*)

The red finned bully was the most widespread and abundant non-galaxiid fish collected (Fig. 6.11). Abundant populations were found in the Rakeahua and Freshwater Rivers, Big Glory Bay Stream, and the two west coast sites, Duck Creek and Waituna Bay Stream (Table 6.3). However, in streams on the east coast, north of Halfmoon Bay, including Maori River, it was rare and only one or two individuals were recorded at any site (Table 6.3, Fig. 6.12). *G. huttoni* appeared to be absent from swifter flowing streams such as Mt. Anglem Tarn and Christmas Village.

Red finned bullies were present in the middle and lower reaches of the rivers in which they were common. In the Rakeahua, bullies were common or abundant in both the mainstem and tributaries, including small first order streams in the middle and lower valley (Fig. 6.10). *G. huttoni* had no apparent preference for stream size, and occurred on a wide range of substrates, and under various flow conditions.

G. huttoni was abundant in runs and shallow riffles, and common in pools, whereas few fish were taken in rapids and cascades. Thus, in the Rakeahua, bullies were less common upstream and were rare in the gorge areas where rapids and cascades predominate (Fig. 6.10). Furthermore, few fish were recorded above these areas. Large numbers of fish were taken on sand and loose gravel/cobble substrata. Immature fish (< 45 mm standard length, McDowall 1965b) were frequently associated with woody debris and dead manuka bushes on sandy substrata in the lower valley.

Inanga (*Galaxias maculatus*)

The inanga was collected from seven catchments (Fig. 6.11) and was

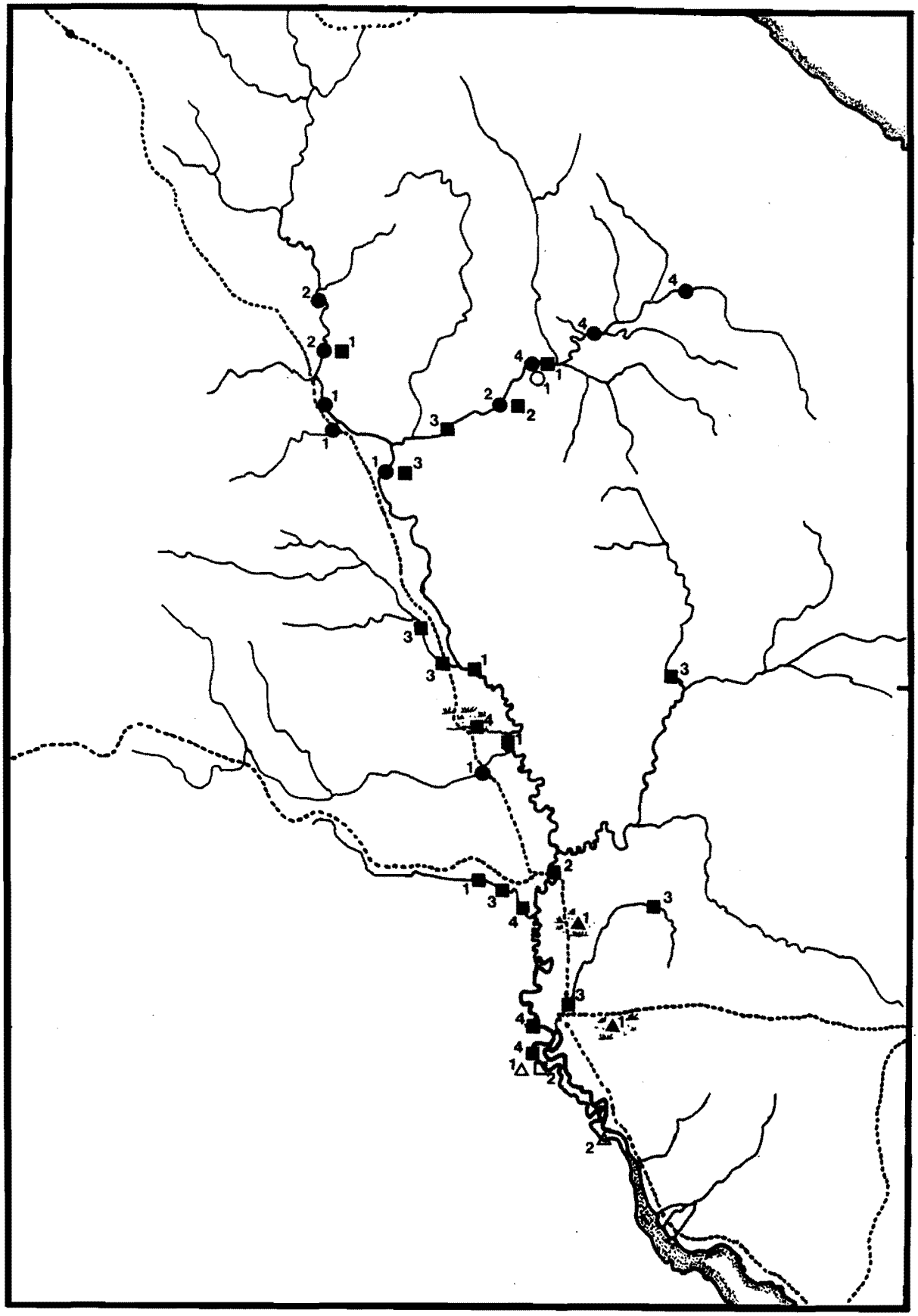

Fig. 6.10. Distribution of *G. vulgaris* (●), *G. huttoni* (■), *Oncorhynchus tshawytscha* (○), *R. retropinna* (□), *Tripterygion nigripenne* (△), and *A. australis* (▲) in the Rakeahua River. 1 = rare, 2 = occasional, 3 = common, and 4 = abundant.

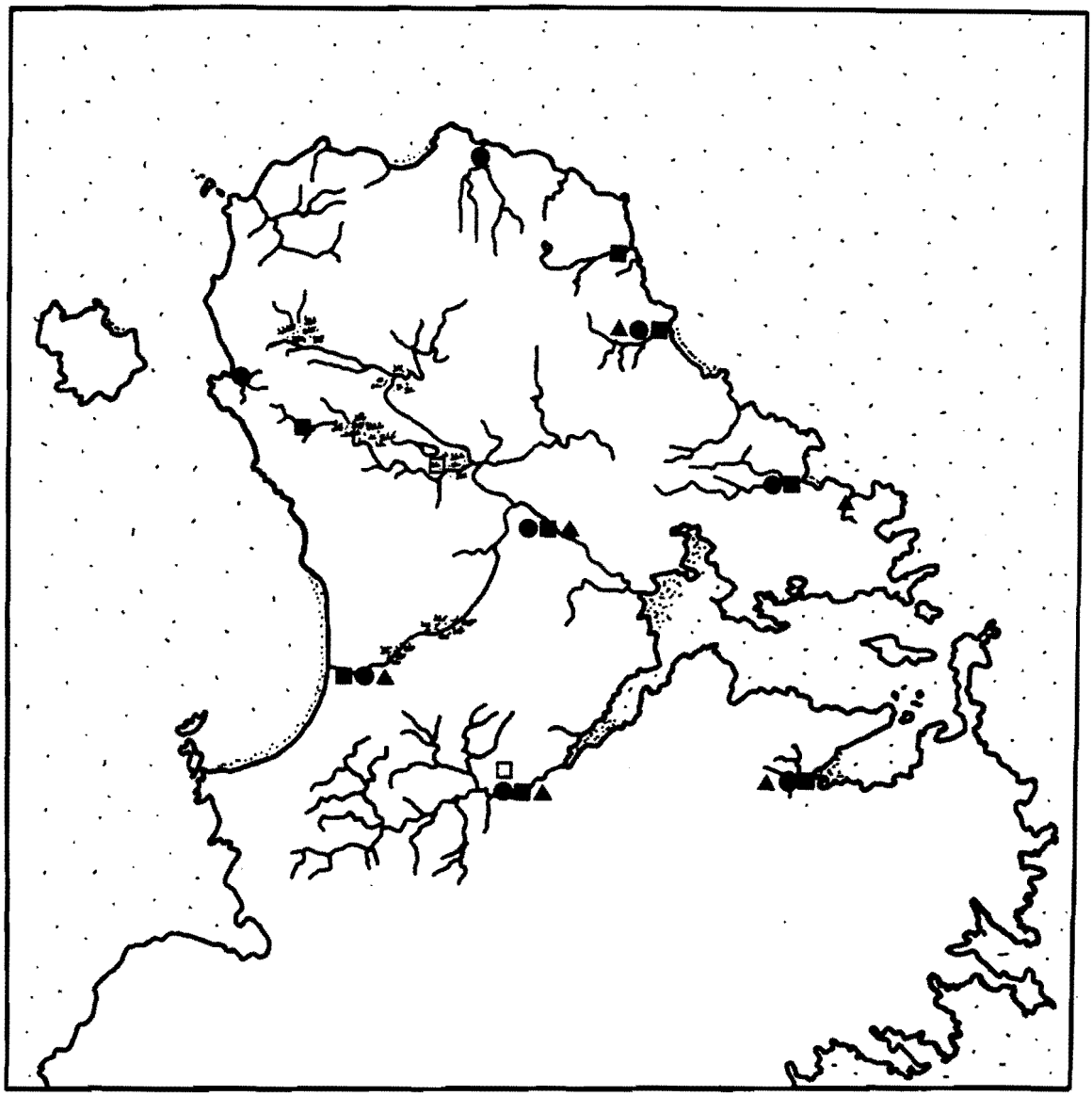

Fig. 6.11. Geographical distributions of *G. huttoni* (●), *A. dieffenbachi* (■), *G. maculatus* (▲), and *A. australis* (□) in northern Stewart Island.

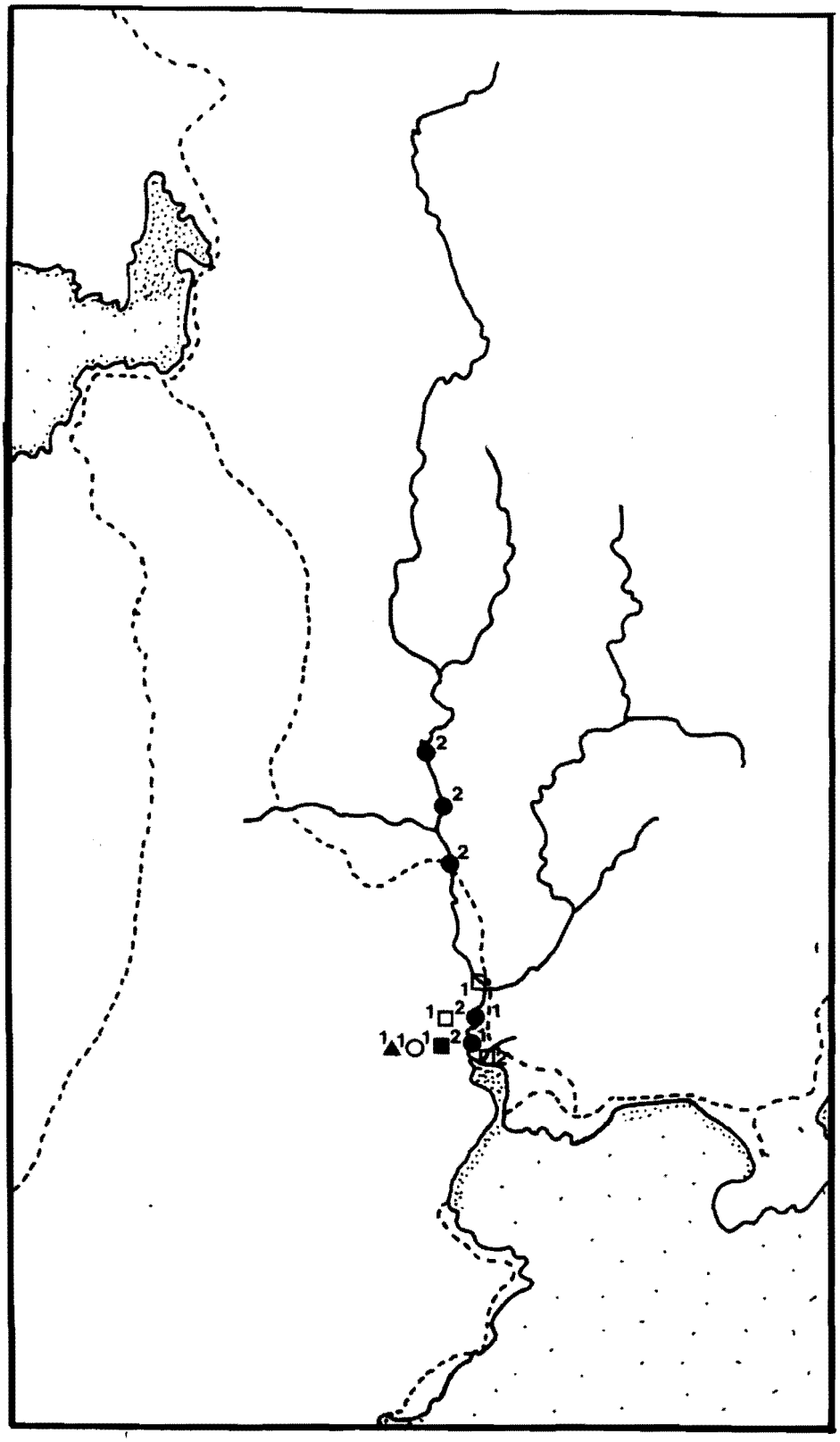

Fig. 6.12. Distributions of *G. huttoni* (■), *G. maculatus* (□), *A. dieffenbachi* (●), *Geotria australis* (▲), and *Tripterygion nigripenne* (○) in the Maori River. 1 = rare, 2 = occasional, 3 = common, and 4 = abundant.

the third most widespread galaxiid. It was abundant in the lower reaches of rivers, particularly tidal reaches of mainstems, and was also abundant in small oxbow lakes on the Rakeahua flood plain (Fig. 6.05). Shoals of inanga were frequently seen in both habitats.

Common smelt (*Retropinna retropinna*)

Smelt were collected from only three catchments (Fig. 6.13), and few fish were encountered.

Giant bully (*Gobiomorphus gobioides*)

A single specimen was caught in a tidal back-eddy opposite the Department of Conservation hut at Freshwater Landing (Fig. 6.13).

Cockabully (*Tripterygion nigripenne*)

The cockabully is only marginally a freshwater species, and is more widespread on the mainland in estuaries and rocky sea-shore habitats (McDowall 1978). On Stewart Island it was recorded in, and slightly upstream of, tidal and estuarine reaches (Figs 6.10, 6.12). It was abundant in the tidal reaches of Murray River (Table 6.3).

Long finned eel (*Anguilla dieffenbachi*)

The long finned eel was, along with the red finned bully, the most widespread non-galaxiid fish (Fig. 6.11). Although widely distributed, it was never abundant: the most fish caught at any one time was five in a double fyke net set in Murray River. Long finned eels were mainly caught in mainstems and tributaries, in the middle and lower valleys of rivers. However, large adult fish were also encountered in the Walkers Hill Basin area of the upper Rakeahua River (Fig. 6.05). Hanchet (ms) divided long finned eels into three size classes: small (<20 cm), medium (20 to 60 cm), and large (>60 cm). On Stewart Island, I encountered few small eels, but both the medium and large size classes were well represented. In the Rakeahua River, medium and large sized eels were collected throughout the river. However, in Maori River, large eels were found only in the lower reaches, whereas medium sized ones were present throughout. Abundance of eels was probably under-estimated, because as medium and large eels could only be collected in fyke nets.

Short finned eels (*Anguilla australis*)

Only two short finned eels were caught. They were taken from

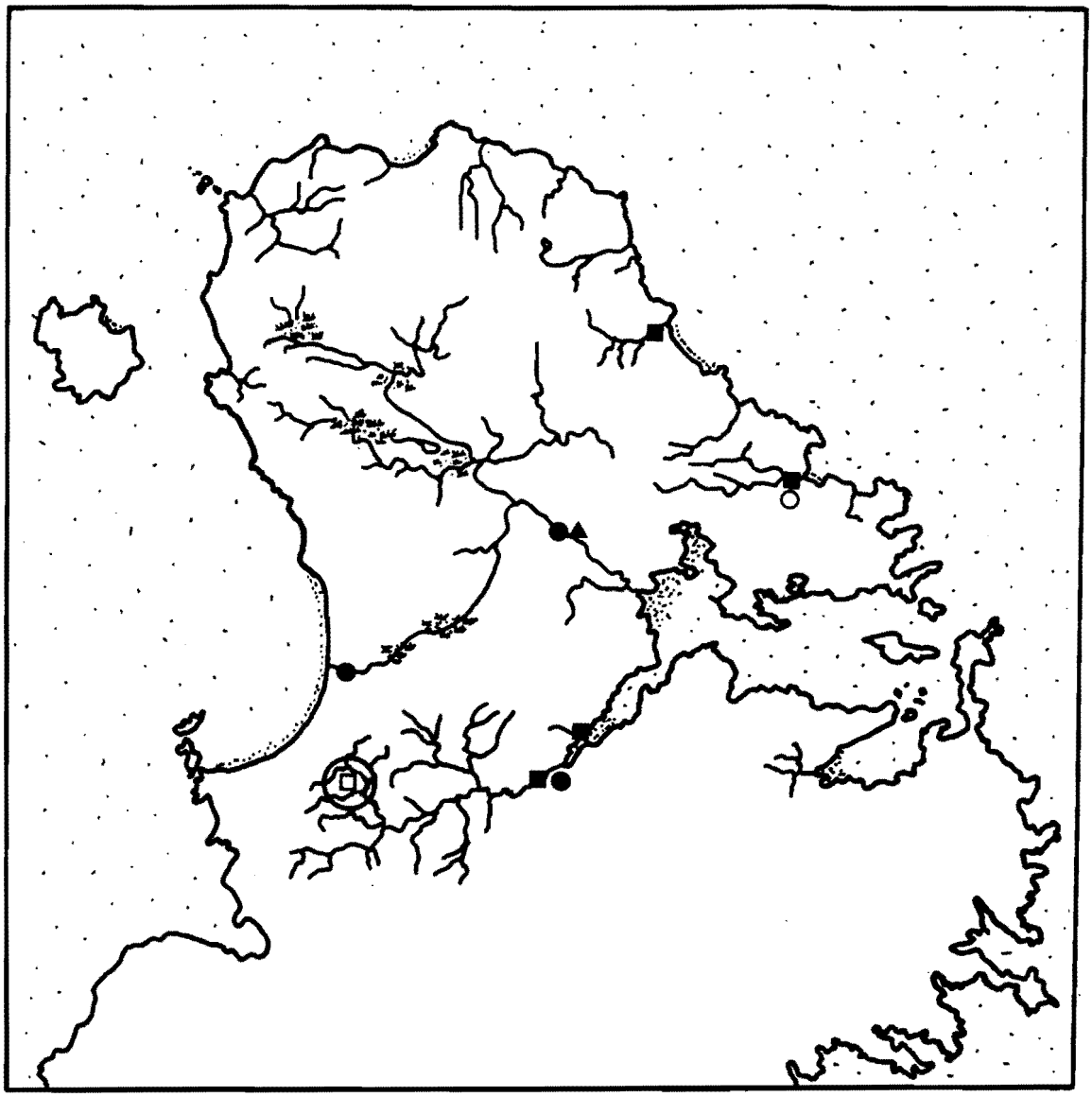

Fig. 6.13. Geographical distributions of *R. retropinna* (●), *Gobiomorphus gobioides* (▲), *Geotria australis* (○), *T. nigripenne* (■), and *O. tshawyscha* (□) in northern Stewart Island.

sluggish pools in the swampy part of the Rakeahua flood plain (Figs 6.10, 6.11).

Lamprey (*Geotria australis*)

One individual was recorded swimming down the Maori River during a small freshet (Figs 6.12, 6.13).

Chinook (quinnat) salmon (*Oncorhynchus tshawytscha*)

A single salmon fry was collected from a run in the Walkers Hill Basin area of the Rakeahua River (Figs 6.10, 6.13), on 19 August 1989.

DISCUSSION

Some species that appeared to have restricted geographical distributions on Stewart Island were probably more widespread than my surveys indicate. In particular, *G. vulgaris* is easily confused with small *G. brevipinnis*, thus individuals could have been misidentified in the field. Electrophoretic studies by R. Allibone confirmed that fish from the Rakeahua River were *G. vulgaris*, however, and preserved specimens collected from Duck Creek and Robertson River were confirmed as the common river galaxiid by R.M. McDowall and G.A. Eldon, (Fisheries Research Division, Christchurch). Available evidence suggests that *G. vulgaris* is present throughout Freshwater Valley, which is connected to Duck Creek by a man-made ditch and swamp. Its presence in the Rakeahua and Robertson Rivers also suggests that it will be found in other large east coast rivers such as Lords, Toitoi, and Kopeka.

Giant bullies (*Gobiomorphus gobioides*) are also likely to be more widespread than my surveys indicate. On the mainland, the recorded distribution of *G. gobiodes* is very fragmented, and in the South Westland Management Evaluation Programme fisheries surveys it was collected from only one site (Eldon 1987). McDowall (1978) and Eldon (1987) believed it is often overlooked because it inhabits tidal and near-tidal reaches that are often inadequately sampled. Such reaches were not extensively sampled on Stewart Island, but the presence of giant bullies in Freshwater River suggests that the species may be present in other large east coast rivers like the Toitoi, Kopeka, and Lords.

Chinook salmon (*Oncorhynchus tshawytscha*) may also have spawned in a number of river systems other than the Rakeahua where they appear to have spawned successfully. An unusual run of chinook salmon in the Mataura River in 1988 was attributed to the escape of about 4000, 3-4 kg fish from a Stewart Island salmon farm (Condie 1988), and adult salmon have been caught off the coast of Stewart Island as far south as Pegasus Bay, and throughout Patersons Inlet (Ron Tindall, Department of Conservation, Stewart Island, pers. comm.).

Suitable spawning habitat probably exists in the Freshwater River and in other large rivers in the south of the island, and the likelihood that these adaptable fish will establish self-sustaining populations is of concern.

The apparently restricted distribution of koaro is consistent with results of mainland studies. Taylor (1988) reported that adult koaro were mainly associated with clear, circumneutral waters, and were rare in acidic brown waters in South Westland. Similarly, on Stewart Island, *G. brevipinnis* was collected almost exclusively from clear, east coast streams with pH ranging from 6.5 to 7.2. The exception was the Maori River which had slightly acidic (pH 6.3 to 6.7), brown water.

The preferred microhabitat of koaro appears to be influenced by the abundance of banded kokopu, such that there is an increasing use of pools, slugs and backwaters where banded kokopu are rarer. Main (1988) suggested that koaro may inhabit shallow, swiftly-flowing reaches to avoid competition with banded kokopu, and he noted that in the absence of banded kokopu, koaro were often abundant in pools as well as riffles. This is consistent with my findings.

With its preponderance of diadromous species, Stewart Island's native fish fauna is largely what would be predicted for a New Zealand offshore island. In fact, except for the addition of *G. vulgaris* and *G. gobioides*, the fauna is the same as that reported for the Chatham Islands (Skrzynski 1967). However, the presence of *G. vulgaris*, a non-diadromous fish, raises a number of biogeographical questions, including, 'how has this purely freshwater species colonised Stewart Island?'

It is generally accepted that during the last ice age (30 000 to 10 000 years ago), Stewart Island was linked to the South Island across Foveaux Strait (Stevens 1980). During this period it is probable that streams originating in "Stewart Island" and "Southland" would have merged

on the large flood plains exposed by the drop in sea level. At such times, purely freshwater species could easily have migrated from Southland into, and up, the Stewart Island branches of these rivers.

However, if this explanation is correct, why are the alpine galaxiid (*G. paucispondylus*), torrent fish (*Cheimarrichthys fosteri*), black flounder (*Rhombosolea retiaria*), common bully (*Gobiomorphus cotidianus*), and blue gilled bully (*G. hubbsi*) not found on Stewart Island, despite being associated with *G. vulgaris* in Southland?

Their absence may be related in part to a lack of suitable habitat. In particular, the absence of large, open, braided rivers with loose gravel beds may have excluded blue gilled bullies and torrent fish. However, appropriate habitat appears to exist for the other species. Rapids in headwater streams with gravel-boulder beds (the preferred habitat of *G. paucispondylus*, McDowall 1978), were not extensively sampled, and therefore this species may have been overlooked. However, as it is commonly associated with *G. vulgaris* this seems unlikely. On the other hand, lowland areas preferred by the common bully and blue gilled bully were extensively sampled and I am confident that they are either absent or very rare.

No mudfish (*Neochanna* spp.) were collected from Stewart Island although suitable habitat appears to exist. They are also unknown from Southland despite extensive searching there (G.A. Eldon pers. comm.).

The presence of *G. vulgaris* and the freshwater crayfish *Paranephrops zealandicus* (see Chapter 4) indicates a freshwater fauna with east coast, South Island, affinities. However, Stewart Island's fish communities do not resemble any east coast fauna found today, and except for a few localities, banded kokopu, giant kokopu, and red finned bullies are rarely found on the east coast, South Island (McDowall 1978, Jellyman 1984, Main 1988, Eldon 1989). In fact, the Stewart Island fish fauna is probably more similar in composition to that reported from the west coast of the South Island (Main *et al.* 1985, Taylor and Main 1987, Eldon 1987, and Taylor 1988). Nevertheless, there are significant differences.

On the South Island's west coast, long finned eels and red finned bullies are the most widespread and numerous species (Main 1989), whereas on Stewart Island, banded kokopu, koaro, and inanga were as widespread as these. Furthermore, giant kokopu and the common river galaxiid were as abundant as *Anguilla dieffenbachi* in some Stewart Island river systems.

In my survey, long finned eels were widespread but never numerically abundant: the most eels caught in a single net was five in Murray River. In the lower Rakeahua and Freshwater Valleys, eels were fished commercially during the 1985/86 summer, so it is probable that they were more abundant prior to this, at least in the lower valley.

However, even in the lower reaches of Maori River, where the eel population has not been exploited, giant kokopu were as abundant as eels, and banded kokopu and koaro were more abundant than eels in the upper reaches (confirmed by night observations). In Murray River (the only other unexploited major river that I sampled intensively) *Tripterygion nigripenne*, inanga (*Galaxias maculatus*) and koaro were all more abundant than eels, indicating that relatively low densities of *Anguilla dieffenbachi* are not unusual on the island.

Giant kokopu appear to be more abundant on Stewart Island than on the two main islands of New Zealand, and were particularly common in the Rakeahua River. Main *et al.* (1985) reported that although giant kokopu were recorded from most apparently suitable sites in South Westland, they were never taken in large numbers: their largest sample was four individuals from a small creek. On Stewart Island, it was common to collect between three and five fish in the commercial double fyke net. In "Hut Stream", a small creek in the lower Rakeahua, over 26 fish were recorded in an approximately 400 m stretch between the main river and the tramping track. Jellyman (1988) suggested that adult giant kokopu move downstream to spawn in autumn. Therefore, the large numbers of fish recorded in the lower Rakeahua in March could reflect a spawning congregation. Nevertheless, repeated counts in "Hut Stream" in August and November also revealed high numbers of fish, so migratory patterns do not provide the full explanation.

Although little is known about the biology of giant kokopu, it has been suggested (McDowall 1978, Jellyman 1979) that individuals are territorial and have home ranges. Observations that I made in "Hut Stream" indicate that territories may be defended at night when usually only one individual occupied any one reach. During the day however, it appears that territorial boundaries may be relaxed, and fish share available cover.

Red finned bullies seem to occupy more diverse habitats on Stewart Island than on the two main islands of New Zealand. They are equally

common on sand, mud and predominantly rocky substrata, whereas in the North and South Islands they have been reported to favour medium velocity streams with beds of loose cobbles and boulders (McDowall 1964a, Eldon 1989, Hanchet and Hayes 1989). Nevertheless, Taylor and Main (1987) sometimes found *G. huttoni* on muddy or sandy beds. McDowall (1964a) reported that typical red finned bully habitats were "immature streams with narrow, V-shaped valleys and little or no flood plains". Yet, on the east coast of Stewart Island, bullies were rare or absent in "immature" streams of this kind, but were abundant in streams flowing into and across the Rakeahua flood plain.

Perhaps the most striking differences between the mainland and Stewart Island fish faunas however, were those exhibited by banded kokopu. *G. fasciatus* is the most widespread fish on Stewart Island, whereas in South Westland it was recorded by Main *et al.* (1985) from fewer sites than 11 other species including the giant kokopu. On Stewart Island, it was collected in large numbers from the mainstems of large rivers and tributaries, whereas on the mainland, various authors (McDowall 1978, Main et. al. 1985, Taylor 1988, Hanchet 1988) have reported that banded kokopu prefer narrow streams. Main (1988) found that the presence of favourable micro-habitats, primarily areas of still or slow flowing water in forested streams, was of major importance in determining its distribution. On Stewart Island, stable stream channels, abundant cover, pools, backwaters, and slugs, and intact forest cover, make some mainstem rivers ideal banded kokopu habitat. In contrast, the apparent absence of appropriate micro-habitats in the mainstems of many west coast South Island rivers, and the catastrophic instream effects of regular flood events probably explains the absence of banded kokopu from them. However, as Main (1988) points out, this does not explain why banded kokopu are absent from many sluggish, stable, spring-fed, single thread rivers, and from the lower reaches of braided rivers where adequate habitat apparently abounds. He concluded, that although untested, competition with brown trout probably resulted in displacement of kokopu from otherwise suitable streams in Westland.

There is little distributional overlap between galaxiids and trout on the main islands of New Zealand (McDowall 1968, 1987, Cadwallader 1975, Main *et al.* 1985, Taylor 1988): in South Westland, banded kokopu were never recorded from any site where adult trout were present (Main *et al.* 1985). The latter authors noted that trout seem to be found principally in the mainstems of rivers, whereas galaxiids tend to occur in

tributaries and headwaters. Similar distributional patterns have been documented in Australia for introduced trout and galaxiids, and it has been suggested that trout exclude native fish from mainstems of Australian rivers, forcing them into smaller, presumably unihabited tributaries (Tilzey 1976, Cadwallader 1979, Jackson and Williams 1980, Fletcher 1987). If this scenario is correct, then the absence of trout from Stewart Island freshwaters has probably enabled banded kokopu to occupy the mainstems of rivers where they can maintain large populations.

There is also some evidence to suggest that the downstream distributional limits of banded kokopu (as seen in the Rakeahua and Maori Rivers) may be defined by competition or predation with giant kokopu, since almost no overlap was found between adults of these species. However, the evidence is circumstantial and I am therefore not in a position to discuss it further. Nevertheless, it is interesting to note that Hanchet (ms) also found banded kokopu were limited to the middle and upper reaches of several tributaries of the Waikato River (North Island), whether giant kokopu were present or absent. He did not consider that interactions between the two species restricted the distributions of either species, but felt that competition with, or predation by long finned eels (Hanchet 1990) was more likely to account for the absence of banded kokopu from downstream pastoral sites. On Stewart Island, exclusion by eels is unlikely because long finned eels are uncommon (see above), and the distributions of large, long finned eels and banded kokopu overlap considerably. Like Main (1988), Hanchet (ms) also considered that the presence or absence of favourable microhabitats, essentially areas of low flow offering refuges and protection from floods, was an important determinant of banded kokopu distribution patterns, and this also seem to be the case on Stewart Island.

Finally, it is interesting to note that there has been some controversy surrounding the consequences of interactions between *G. vulgaris* and brown trout (*Salmo trutta*). In a recent letter to *Freshwater Catch* (Spring 1989), M.A. Rodway (Manager, Southland Acclimatisation Society) noted that in the presence of brown trout, *G. vulgaris* occupied the swiftest rapids and riffles of the Oreti River, and was especially associated with coarse substrata. On Stewart Island, such habitats were the least utilised by common river galaxiids, and my observations indicate that *G. vulgaris* prefers shallow riffles and runs

with slower flows and smaller loose gravel substrata. These are the habitats occupied by trout in the Oreti River, according to Rodway. Glova (1989) suggested that the microhabitats occupied by *G. vulgaris* in the Oreti River had been compressed by interactions with 'behaviourally dominant' brown trout, which had excluded them from their preferred habitat. My observations on Stewart Island support Glova's contention.

In combination, these observations indicate that the range of habitats and reaches occupied by any one species can be extremely broad. This is in accordance with the contention that the stream faunas of New Zealand include numerous generalists and opportunistic species that have successfully evolved mechanisms to cope with highly variable environments (Winterbourn 1986). Furthermore, these observations emphasise that various abiotic and biotic factors can influence distribution patterns, both on Stewart Island and on the two main islands of New Zealand, and that there is a very real need for a greater knowledge of the behavioural interactions, migratory and territorial patterns, and microhabitat requirements of the fish species.

CHAPTER 7

THE DIET OF BANDED KOKOPU (*GALAXIAS FASCIATUS*), AND RED FINNED BULLIES (*GOBIOMORPHUS HUTTONI*) ON STEWART ISLAND

INTRODUCTION

The banded kokopu (*G. fasciatus*) is the most abundant and widespread of a group of three rather similar, large galaxiids endemic to New Zealand (Main 1988). However, it is largely restricted to forested catchments and there is some evidence of habitat compression through interaction with behaviourally dominant trout (Main *et al.*, 1985, Taylor 1988). Banded kokopu appear to have specialised habitat requirements and a preference for narrow forested streams has been reported (Taylor 1988). The diet has been poorly studied, and in the only published account, Main and Lyon (1988) showed that in South Westland, banded kokopu fed predominantly on terrestrial invertebrates, that they appear to select from drift.

The red finned bully (*G. huttoni*) is also widespread and abundant, occurring throughout the North and South Islands (the mainland) (McDowall and Richardson 1986). The biology and diet of *G. huttoni* were fairly extensively studied in the Makara stream near Wellington by McDowall (1964, 1965a & b), who found they fed almost exclusively on aquatic invertebrates. Red finned bullies are usually found in small, stony bedded streams at low altitudes, and have rarely been taken from sandy or muddy habitats (Taylor 1988).

On Stewart Island, banded kokopu and red finned bullies are widespread and abundant, however, both commonly occupy habitats other than those in which they are found on the mainland (see Chapter 7). I frequently collected banded kokopu from mainstem reaches as well as small streams, and bullies were as common in sandy bottomed streams as rocky ones. In these different habitats, benthic invertebrate communities can be expected to differ (Chapter 4) and so can the kinds and amounts of drift organisms derived from the riparian zone.

The primary objective of this study was to describe food resources utilized by each species, to determine whether the diets of bullies

living in sandy or stony bedded streams on Stewart Island differed, and whether diets differed from those described in mainland studies by McDowall (1965a) and Main (1988).

METHODS

Dietary studies

Gut contents of 15 *G. fasciatus* and 37 *G. huttoni* were examined. I was unwilling to kill larger numbers of fish to obtain what appeared to be very little additional information based on my initial analyses. Furthermore, Eldon (1979) recommended that only small samples should be necessary in galaxiid studies where the aim was simply to record the kinds and abundance of prey in the diet.

Banded kokopu were collected at night on two occasions (21 February 1989, 6 April 1989) from mainstem habitats in Maori River. They were taken from three backwaters in a stony stretch of the river with dense overhanging podocarp vegetation.

Fish were anesthetized and killed with an over-dose of Benzocaine, and then preserved in 4 to 10 % formalin after injecting their stomachs with the preservative. Fish ranged from 11.7 to 18.5 cm, total body length.

Bullies were collected in the early morning from "Stream One", Rakeahua Valley. Seventeen fish were taken from stony reaches on 5 March 1989. At this collection site the stream was 1.5 m wide and had podocarp/manuka mixed riparian vegetation. On 14 August 1989, 20 bullies were collected from sandy, lower reaches of "Stream One" at a point where the stream meandered through manuka scrub on the Rakeahua flood plain. Fish were anesthetized, killed and preserved as before. Only adult fish were collected and they ranged from 50 to 73 mm and 56 to 84 mm long at stony and sandy sites, respectively.

In the laboratory, alimentary canals were removed from fish after severing the oesophagus at the pharynx, and the rectum at the anus. Contents were distributed in a Bogorov sorting tray and identified under a binocular microscope at up to 40X magnification. Contents of whole alimentary tracts of *G. huttoni* were examined as food items throughout the gut could be recognised and counted. In contrast, only stomach

contents of *G. fasciatus* were examined. However, the rest of the gut was checked for parasites, and body parts that might help identify well digested stomach contents. Benthic invertebrate samples were also collected from each site on the day following fish collection. Unfortunately, samples taken from stony sites in "Stream One", were lost, and benthic samples collected two months later (9 May 1989) had to be used instead in subsequent analysis. Each site collection consisted of five benthic Surber samples (0.1 m^{-2}, 0.25 mm mesh).

Twenty four hour drift samples were collected from Maori River and "Stream One" on two occasions, (26 February, 7 April 1989 (Maori River); 12 March, 10 May 1989, ("Stream One")). Paired drift nets (0.3 mm mesh, 30 by 15 cm opening, 100cm long) were arranged with rock dam leaders (Fig.7.1) which channelised surface flows into either net. Individual net collections were therefore not replicates of each other but together provided a representative sample of both aquatic and terrestrially derived drift fauna. Drift samples were preserved in 4 to 10 % formalin and sorted later in the laboratory.

Terrestrial invertebrates were identified to class, order, or occasionally to phylum, whereas aquatic invertebrates were generally identified to genus or family. Small Diptera (< 3 mm long) and Acarina were discarded as numerically they accounted for about 36 % of total drift and they were probably too small to be seen by *G. fasciatus* and were not found in their guts.

Four indices were used to describe and compare the diets of bullies and banded kokopu. Percentage frequency of occurrence (FO), relative abundance (RA), and relative gravimetric composition (GC) were calculated along with Jacobs' selectivity index (D).

Gravimetric values were based on dry weights of undigested prey items, estimated by calculating the average dry weight of five representative, intact individuals of respective taxa. Animals were oven dried at 66^{o}C for 48 hours and weighed on a Mettler AJ100 balance to the nearest 10 micrograms.

Relative abundance and gravimetric composition of gut contents were compared with benthos and total drift (the latter for *G. fasciatus* only) by calculating Spearman's rank correlation coefficient (STATISTIX NH Analytical Software).

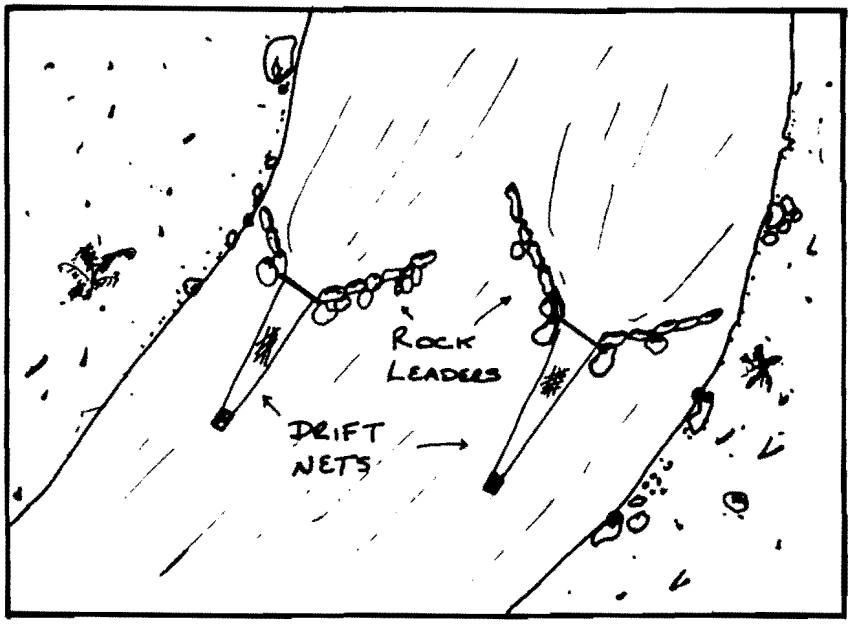

Fig. 7.1. Paired drift nets were set with rock dam leaders to collect total surface drift.

Jacobs' index (Jacobs 1974) is a modification of the forage ratio and Ivlev's electivity index (Ivlev 1961) and has the formula:

$$D = \frac{r - p}{r + p - 2.r.p}$$

where r = proportion of the item of interest in the gut.
p = proportion of the item in the environment ("community").

Values of D can range from 1.0 for high positive selection to -1.0 for complete avoidance. Values greater than 0.6 were assumed to be significant as is conventional (Zaret and Rand 1971; Fechney 1988).

Stable carbon isotope analysis

The rationale behind stable carbon isotope (SCI) analysis has been described by Main (1988) and is summarised below.

The SCI technique enables a degree of discrimination to be made between sources of food (e.g., terrestrial v. aquatic) assimilated and incorporated as biomass by fish prior to sampling. The technique uses differences in natural abundances of the stable carbon isotopes ^{13}C and ^{12}C as tracers, which move with little alteration through food chains (Rounick and Winterbourn 1986). It is possible to distinguish between terrestrial and aquatic food sources, because terrestrial and aquatic plants often fractionate the two carbon isotopes to differing degrees (Rau 1980). The ratio of ^{13}C to ^{12}C in a consumer's tissue provides a summary of the animal's recent feeding history (Fry and Arnold 1982) and reflects only materials actually converted into tissue (Rounick and Winterbourn 1986).

Aquatic invertebrates, banded kokopu, and terrestrial invertebrates were collected from the Maori River Valley for SCI analysis. Banded kokopu were provided by R. Allibone (University of Otago) who collected fish on 22 February 1989, from two localities in the valley. They were a small pond offset from the main tributary at its confluence with the mainstem, and a site in the main river just below the upper swing bridge on the Link track. Red finned bullies were collected from "Stream One", Rakeahua Valley in August 1989. Head capsules and legs of several representatives of each major invertebrate taxon were pooled for analysis (total sample dry weight about 10 mg). Samples of muscle were removed from the caudal peduncles of five fish and oven dried at 66°C before being sent to the Institute of Nuclear Sciences, DSIR, Lower Hutt, for analysis. By convention, results of ^{13}C values are expressed as the

relative difference per mille (‰), between the isotope ratio of the sample and that of the international PDB (Pee Dee Belemnite) carbonate standard (Craig 1957).

RESULTS

Red finned bully (*Gobiomorphus huttoni*)

(a) Fish from stony substrata

Gut contents of 17 bullies taken from stony bedded reaches of "Stream One" were examined. In total, 285 prey items were identified (Table 7.1).

Numbers of food items ranged from 1 to 39 per fish (average = 16) and all gastric stomachs contained prey. Numerically, gut contents were dominated by Chironomidae (31.9 %) although Leptophlebiidae (Ephemeroptera), Plecoptera, *Austrosimulium* (Diptera), and Amphipoda accounted for a further 44 %. Leptophlebiidae, Amphipoda and Chironomidae were the most frequently occurring prey, although plecopterans and Hydrobiosidae occurred in over 50 % of all stomachs examined.

Gravimetrically, *Coloburiscus humeralis*, Leptophlebiidae, Hydrobiosidae, and to a lesser extent Amphipoda and Plecoptera were the most important prey groups.

Benthic invertebrate samples taken from "Stream One" contained a diverse fauna, and although *C. humeralis*, Amphipoda, and Chironomidae accounted for 50 % of the fauna, numerically, six other taxa (Leptophlebiidae, Plecoptera, cased caddis, Hydraenidae, Elmidae, and Simuliidae) each accounted for between four and ten percent (Table 7.1).

With the exception of some terrestrial invertebrates (lepidopteran larvae and Gastropoda), only rare prey items (less than 1.5 % of the fauna) were selected in numbers significantly greater than their abundance in the benthos (Table 7.1). The relative abundance of prey items in fish guts was significantly correlated with that in the benthos (r_S = 0.66, $P < 0.01$). However, 20 % of taxa were significantly avoided including *C. humeralis* (D = -0.70) and cased caddis (D = -0.65), both of which were abundant in the benthos.

Table 7.1. Relative abundance (%), frequency of occurrence and gravimetric values of invertebrates in the benthos and diet of *G. huttoni* on stony substrata in "Stream One". Jacobs' selectivity index scores are also given, (fish n = 17, surbers n = 5).

Species	Gut contents	Benthic samples	Jacobs index	Freq. of occurence	Weight (mg)
Ephemeroptera					
Leptophlebiidae	11.90	8.81	0.166	76.5	35.36
Coloburiscus sp.	3.90	18.73	-0.70	41.2	46.20
Other	0.70	0.074	0.81	11.8	2.08
Plecoptera					
A.cyrene	2.10	1.42	0.197	35.3	18.12
Gripopterygidae	8.40	8.58	-0.02	52.9	19.44
M. grandis	0.70		1.0	11.8	3.72
Trichoptera					
Hydrobiosidae	5.26	1.87	0.49	52.9	33.60
Philopotamidae	1.80	0.97	0.30	11.8	3.80
Other	1.80	7.99	-0.65	29.4	1.20
Diptera					
Chironomidae	31.90	13.66	0.5	70.6	1.09
Simuliidae	11.60	4.40	0.48	41.2	3.30
Ceratopoginidae					
Other	0.70	2.46	0.056	5.9	
Coleoptera					
Scirtidae	1.40	0.15	0.81	17.6	1.44
Hydraenidae	1.40	5.45	-0.6	17.6	0.32
Elmidae	1.40	5.15	-0.59	23.5	1.28
Hydrophilidae	1.10		1.0	17.6	0.75
Amphipoda					
C.rivertonensis	9.50	16.19	-0.3	76.5	24.30
Other aquatic invert.	0.40	3.51	-0.8	5.9	
Other terrestrial invert.	4.20	0.60	0.76	23.5	1.26

(b) Fish from sandy substrata

Gut contents of 21 bullies collected from sandy reaches of "Stream One" were examined and 142 prey items were recorded (Table 7.2). Numbers of prey items per fish ranged from 1 to 25 (average = 7).

Stomach contents were dominated numerically by Chironomidae (41.5 %) and to a lesser extent Amphipoda (18.3 %, Table 7.2). These two groups were also the most frequently occurring prey items (76 and 52 % of fish examined, respectively). Ceratopogonidae, Scirtidae, and Plecoptera, each represented about 7 % of prey items consumed, although gravimetrically the contribution of stoneflies was much greater than that of the other two, and was only exceeded, by Amphipoda.

Diversity of the benthic invertebrate fauna was poor in sandy reaches and four taxa (Chironomidae, Scirtidae, Amphipoda, Oligochaeta (88 % of the "other aquatic" group)) accounted for 86 % of all invertebrates taken in Surber samples (Tables 7.2). Plecoptera and Ephemeroptera were rare and only one coleopteran species was recorded.

Some selection of prey items other than rare groups was apparent, and 50 % of taxa had selectivity scores greater than 0.35. However, of the abundant taxa only terrestrial invertebrates and *A. cyrene* had Jacobs' index scores greater than the "significant" 0.60 level. Also, the relative abundance of prey items in guts was significantly correlated with the relative abundance of potential prey items in the benthos (r_s = 0.78, $P < 0.01$). The diets of bullies collected on sandy and stony substrates were dissimilar (r_s = -0.03, Tables 7.1, 7.2) and bullies from the latter habitats ate greater numbers of Ephemeroptera, Plecoptera and Trichoptera. Furthermore, on average, almost twice as many prey items were present in stomachs of bullies taken from stony substrata.

Banded kokopu (*Galaxias fasciatus*)

Dietary information was obtained from 15 banded kokopu collected from Maori River. Aquatic amphipods were the most abundant prey items recorded, although 83 % occurred in a single stomach and almost all the others (15 %) had been eaten by one other fish (Table 7.3). Terrestrial invertebrates accounted for 68 % of all remaining prey items. Of these, Carabidae were numerically dominant, occurring in 67 % of fish and accounting for 21.4 % of prey items recorded. Lepidopteran larvae, adult Plecoptera, Arachnida, and large adult Diptera (>3mm long) accounted for

Table 7.2. Relative abundance (%), frequency of occurrence and gravimetric values of invertebrates in benthos and the diet of *G. huttoni* on sandy substrata in "Stream One". Jacobs' selectivity index scores are also given, (fish n = 20, surbers n = 4).

Species	Gut contents	Benthic samples	Jacobs index	Freq. of occurence	Weight (mg)
Ephemeroptera					
Leptophlebiidae		1.26		4.8	1.04
Coloburiscus sp.					
Other	0.7		1.0		
Plecoptera					
A.cyrene	2.8	0.38	0.77	19	12.08
Gripopterygidae	0.7	0.31	0.39	4.8	0.81
M.grandis	4.2	1.38	0.52	19	11.16
Trichoptera					
Hydrobiosidae	0.7	0.57	0.07	4.8	2.24
Philopotamidae					
Other	1.4	0.63	0.38	9.5	0.48
Diptera					
Chironomidae	41.5	38.77	0.057	76.2	0.71
Simuliidae	2.1	1.76	0.09	14.3	0.30
Ceratopogonidae	7.0	2.33	0.52	23.8	1.40
Other	6.3	2.1	0.52	38.1	
Coleoptera					
Scirtidae	7.0	19.9	-0.53	23.8	3.60
Hydraenidae					
Elmidae	0.7		1.0	9.5	0.32
Hydrophilidae					
Amphipoda					
C.rivertonensis	18.3	13.97	0.16	52.4	23.40
Other aquatic invert.	0.7	15.52	-0.93	4.8	
Other terrestrial invert.	5.6	0.63	0.81	28.6	

Table 7.3. Relative abundance (%), and frequency of occurrence of invertebrates occurring in benthos, drift and the diet of *G. fasciatus* from Maori River. Jacobs' selectivity index scores are also given, (fish n = 15, surbers = 5, drift samples from both sites (n = 4, 24 hour samples, 2 nets/night) combined).

	Relative Abundance				Jacobs Index of Selection (D)		Freq. of Occurance
	Gut		Drift	Benthos	Drift	Benthos	
Species	Total	excluding amphipoda					
	invert.						
Arachnida	3.76	10.02	6.2	-	-0.26	1.00	46.7
Hemiptera	1.13	3.06	3.2	-	-0.49	1.00	26.7
Hymenoptera	0.75	2.04	3.9	-	-0.69	1.00	13.3
Collembula	0.75	2.04	3.2	-	-0.63	1.00	13.3
Coleoptera							
Carabidae	7.90	21.40	0.0	-	0.99	1.00	66.7
Curculionidae			1.0	-	-1.00		0.0
Staphylinidae			1.1	-	-1.00		0.0
Other	0.38	1.02	3.6	-	-0.81	1.00	6.6
Lepidoptera							
Larvae	4.13	11.22	2.1	-	0.34	1.00	40.0
Adults	0.75	2.04	0.9	-	-0.09	1.00	6.6
Diptera							
(>3mm)	3.38	9.18	8.0	-	-0.43	1.00	26.7
Other	3.01	8.16	1.6	-	0.31	1.00	33.3
Amphipoda	63.16		9.3	67.9	0.89	-0.10	40.0
Plecoptera	3.76	10.20	11.1	4.2	-0.52	-0.06	40.0
Ephemeroptera	0.75	2.04	3.8	6.4	-0.68	-0.80	13.3
Coleoptera	1.13	3.06	2.9	3.0	-0.45	-0.46	20.0
Trichoptera	1.13	3.06	3.0	5.4	-0.46	-0.66	20.0
Diptera							
Chironomidae	1.13	3.00	16.3	8.8	-0.72	-0.79	13.3
Simuliidae	1.13	3.06	21.3	3.0	-0.79	-0.46	20.0
Other	0.38	1.02	0.7	0.6	0.19	-0.23	6.6
Decapoda	1.88	5.10			1.00	1.00	26.7
Other	0.38	1.02		0.8			6.6

a further 40 % of prey, but each of them occurred in only about 40 % of the fish examined (Table 7.3). Gravimetrically, Carabidae were the most important dietary items observed (92.6 %) and the only other groups to contribute more than 1 % of stomach content biomass were Arachnida, lepidopteran larvae, Amphipoda, and Plecoptera (Table 7.4).

Drift was dominated by aquatic invertebrates (68.4 %) with Simuliidae, Chironomidae, Plecoptera, and Amphipoda accounting for 85 % of this total (Table 7.3). Arachnids and large Diptera were the most abundant terrestrial groups in drift samples. Carabidae contributed less than one percent of total drift, but smaller coleopterans (< 5 mm long) were more common.

Carabidae and Amphipoda were the only items that were significantly over represented in guts compared with drift (D = 0.99, and 0.89, respectively), although there was no correlation between the rank order of items in drift samples and fish gut contents (r_s = 0.01).

Three *G. fasciatus* stomachs contained unidentifiable white tissue, which was boneless, and may have been *Paranephrops* flesh. This was suggested by the presence of chitinous plates in one fish and a crayfish leg in another. No *Paranephrops* were encountered in benthic or drift samples from the Maori River (although they were recorded from the river in small numbers) and therefore they were not included in the analyses. However, this "crayfish material" made up more than 60 % by volume of the stomach contents of fish containing it and therefore it was important.

Stable carbon isotope analysis

Results of stable carbon isotope analysis suggested that the diets of bullies and banded kokopu were dominated by prey of terrestrial origin as average $\delta^{13}C$ values (-24.8 °/‥ and -26.5 °/‥, respectively) fell within the range of $\delta^{13}C$ values for terrestrial prey items (-23.4 to -26.8 °/‥, Table 7.5).

Three of the five banded kokopu sampled had $\delta^{13}C$ values (average = -25.7 °/‥) that were most similar to those of Coleoptera, Orthoptera, and Blattodea (Table 7.5), large prey items that were recorded in the stomachs of fish. The more negative stable carbon ratios of the other two fish, suggest a greater contribution by aquatic organisms.

Table 7.4. Gravimetric values and associated Jacobs' selectivity index scores of invertebrates occurring in the benthos, drift and the diet of *G. fasciatus* from Maori River, (fish n = 15, surbers = 5, drift samples from both sites (n = 4, 24 hour samples, 2 nets/night) combined).

	Gravimetric % weight		Jacobs Index of Selectivity (D)
	Gut	Drift	Drift
Species			
Arachnida	1.72	19.92	-0.87
Hemiptera	0.06	1.12	-0.90
Hymenoptera	0.05	1.69	-0.94
Collembula	0.01	0.22	-0.95
Coleoptera			
Carabidae	92.60	0.02	0.99
Curculionidae			-1.00
Staphylinidae			-1.00
Other	0.12	0.62	0.68
Lepidoptera			
Larvae	1.63	5.78	-0.57
Adults	0.02	0.18	-0.80
Diptera			
(>3mm)	0.30	4.97	-0.89
Other	0.86	4.25	-0.67
Amphipoda	1.22	1.26	-0.07
Plecoptera	1.89	39.00	-0.94
Ephemeroptera	0.36	12.56	-0.95
Coleoptera	0.06	0.99	-0.89
Trichoptera	0.33	6.07	-0.90
Diptera			
Chironomidae	0.00	0.27	-0.98
Simuliidae	0.01	0.96	-0.98
Other	0.01	0.13	-0.19

Table 7.5. $\delta^{13}C$ values of potential invertebrate prey and muscle tissue from Stewart Island fish.

Aquatic insects	$\delta^{13}C$	Terrestrial insects	$\delta^{13}C$
Deleatidium spp.	-30.8	Orthoptera (weta)	-25.8
*Coloburiscus*sp.	29.0	Coleoptera (Carabidae)	-25.3
Stenoperla prasina	-27.8	Hymenoptera	-24.5
Austroperla cyrene	-27.5	Blattodea	-25.8
Zelandoperla spp.	-29.4	Araneae	-26.0
Hydrobiosidae	-28.5	Opilones	-26.0
		Diplopoda	-23.4
		Amphipoda	-26.8

Gobiomorphus huttoni	$\delta^{13}C$	*Galaxias fasciatus*	$\delta^{13}C$
Individual 1	-24.2	Individual 1	-25.6
2	-24.3	2	-27.0
3	-24.8	3	-25.6
4	-26.0	4	-28.5
5	-24.5	5	-25.9
Average + 1SE	-24.8 + 0.29		-26.5 + 0.50

The $\delta^{13}C$ values obtained for red finned bullies (average ^{13}C = -24.8 °/••) were not consistent with stomach content records, however,and suggest a predominantly "terrestrial based" diet, rather than an aquatic one. These apparently anomalous results are nevertheless consistent with those obtained by Rounick and Hicks (1985) for red finned bullies from a southern North Island stream, and suggest that isotope fractionation by *G. huttoni* may be unexpectedly high. They could also reflect a more ^{13}C-enriched juvenile diet, but as estimates of ^{13}C turnover times for fish are not presently available (Rounick and Hicks 1985) it is impossible to predict ^{13}C retention times and so test this hypothesis. However, if retention times are long and can be measured in years, ^{13}C enrichment could well be influenced by juvenile diet. Red finned bullies are diadromous and presumably juveniles feed at sea and in estuarine habitats. Estuarine animals are typically ^{13}C enriched and tend to have values within the range of terrestrial species (Gearing et.al. 1984).

Parasites

Infestations of the nematode, *Hedruris spinigera* were recorded in the gastric stomachs of *G. fasciatus*. Numbers of *H. spinigera* ranged from one to 25 per fish and in all 71 were recorded from eight of 15 fish. Infestations by acanthocephalans (1 to 6 per fish, total = 32) were also recorded in the upper intestine, just below the pyloric sphincter of 12 of the 15 fish.

Only one nematode and a number of protrusions that appeared to be metacercarial cysts were collected from a single bully taken from Freshwater River. No parasites were recorded from fish taken from "Stream One".

These results suggest that parasite loadings of banded kokopu are low, and in particular the numbers of Acanthocephala found were much lower than the 1143 reported by McDowall (1978) from 9 inanga (*Galaxias maculatus*).

DISCUSSION

Gobiomorphus huttoni

Results of gut content analyses made on *G. huttoni* were consistent with those obtained in other studies (McDowall 1965b) and showed that red finned bullies feed almost exclusively on aquatic benthic invertebrates.

Significant correlations between dietary composition and benthic invertebrate samples at sandy and stony bedded sites in "Stream One" suggested there was very little prey selection, a contention supported by the Jacobs' index scores. McDowall (1965a) suggested that red finned bullies were selective feeders because the fish he examined exhibited low food diversity, yet high numbers of individual prey taxa were present. This kind of pattern was not shown by the Stewart Island fish I examined, but rather they had high diversity (up to 11 prey types per fish, c.f., McDowall's maximum of eight) and lower numbers of total prey per fish (maximum = 39individuals, c.f., McDowall's maximum of 332).

The recognition of selective feeding is a fundamental problem associated with the analysis of stomach contents and benthic samples, because it is almost impossible to distinguish between prey items that are available (i.e., present in the benthos) but not consumed, and items that are present in the benthos but not available or encountered (Werner and Hall 1974). Differences in prey availability that were not obvious from the makeup of benthic invertebrate samples, may therefore account for the greater apparent selectivity of fish taken from sandy substrata.

The occurrence of terrestrial invertebrates in guts suggests that *G. huttoni* also feeds opportunistically. Selectivity, and opportunism need not be mutually exclusive as seems to have been inferred by some other workers (e.g., Sagar and Eldon 1983, Scrimgeour 1987). Thus, the bully, *G. hubbsi* has been shown to be a selective feeder (Scrimgeour 1987), although where food availability is poor, it (*G. hubbsi*) may also be opportunistic (Sagar and Eldon, 1983).

It is well known that certain kinds of benthic invertebrates are avoided by predatory fish, and both McDowall (1965a) and Percival (1932), found that *G. huttoni* avoided Plecoptera even though stoneflies were common components of the benthos. This contrasts strongly with my findings that large, late instar stoneflies (*Austroperla cyrene*, *Megaleptoperla grandis*, *Zelandoperla* spp. and *Zelandobius* spp.) were important components of the diet, especially in sandy reaches. McDowall (1965a) also noted that the mayfly *Coloburiscus humeralis* was avoided as prey even though it was abundant in typical bully habitats, and suggested that its large size, together with its hard exoskeleton and external gills, may account for this behaviour. Similarly, on Stewart Island, *C. humeralis* was taken in much lower numbers than would be expected, based on its abundance in the benthos, but despite this it was an important

component of the diet in gravimetric terms. Cased caddisflies were also poorly represented in the gut contents of Stewart Island and Makara River fish (McDowall 1965a).

Galaxias fasciatus

Banded kokopu fed principally on drifting terrestrial invertebrates, which numerically and gravimetrically accounted for most of the food taken. However, the occurrence of a large numbers of amphipods and tissue suspected to be that of *Paranephrops zealandicus* in a few fish, suggests they are also opportunistic feeders able to take advantage of a locally abundant or rich food source. These conclusions were supported by the carbon isotope analyses which indicated a predominantly terrestrial diet.

My results are consistent with the findings of Main and Lyon (1988) for banded kokopu in streams of South Westland. Thus, in both studies terrestrial Coleoptera of the family Carabidae were the most abundant and frequently taken prey (excluding Amphipoda) and gravimetrically they were an extremely important component of the diet.

G. fasciatus feeds while maintaining station in the water column (Eldon 1969, Main 1988) and takes prey that are on the water surface or sinking through the water. Main considered this habit accounted for the predominance of terrestrial invertebrates in banded kokopu diet and he also considered that they positively selected larger prey items. Large Coleoptera in particular may be selected because of their size (Main 1988), and it is noteworthy that in my study Carabidae (all > 10mm long) were much more common in stomach contents than drift samples. In contrast, smaller Coleoptera (Curculionidae, Staphylinidae, and some other beetles, all < 5 mm long) were a much more common component of the drift but were significantly under-represented in banded kokopu stomachs. It is possible that gut passage times are longer for larger beetles than for smaller prey items and as a result their importance may be exaggerated. Nevertheless, they are clearly major dietary components.

In summary, dietary information is generally consistent with findings from mainland studies and observed differences in the distributions of *G. fasciatus* and *G. huttoni* are probably not related to differences in food resource availability or utilisation.

Red finned bullies are benthic feeders on aquatic prey, whereas banded kokopu are drift feeders that take prey predominantly of terrestrial origin. Both appear to be opportunistic feeders able to take advantage of locally abundant or rich food sources.

CHAPTER 8

SYNOPSIS

Taxonomically, the stream fauna of Stewart Island is not very different from that found in the rest of New Zealand, with a preponderance of common mainland taxa. Few new species were collected, and it is possible that those that were, may be present in Southland or Fiordland, as the faunas of these area are also poorly known. Like the mainland, the freshwater fauna is characterised by generalist and opportunistic species, a contention supported by my leaf pack and dietary studies.

The numerically dominant benthic invertebrates in most streams, were species of Amphipoda, Oligochaeta, and Chironomidae, with Ephemeroptera, Plecoptera, Simuliidae and Coleoptera of secondary importance. Correlative and DECORANA analyses suggested that community types are influenced by the presence of moss on stream bed substrata, although there were also locally distinct faunal groupings that may in part reflect differences in pH, conductivity, and vegetation cover. These three factors also showed geographic patterns that were reflected in the fauna. Thus, an east coast/Rakeahua Valley fauna, was characterised by a high relative abundance of Chironomidae, Oligochaeta, stoneflies and mayflies and low numbers of amphipods, and was associated with clear circumneutral waters, low conductivity and predominantly podocarp forest. Conversely, the north western stream faunas included a greater abundance and diversity of Amphipoda and was associated with brown, acidic waters with high conductivity, and often, but not always, riparian, coastal scrub.

Experimental studies at 6 sites in the Rakeahua river system indicated that leaf litter breakdown (kamahi leaves) rates were rapid at headwater sites where feeding by shredders (principally *Austroperla cyrene*) was high. In contrast, breakdown rates were slower at mainstem sites eventhough the large detritivore/carnivore, *Austridotea benhami* was present.

The fish species collected from Stewart Island were largely diadromous forms. One species, *Galaxias vulgaris* is non-diadromous, however, and its appearance suggests a former link with the South Island, presumably during the Otira glaciation. The presence of *G. vulgaris* and

the crayfish, *Paranephrops zealandicus* also indicate affinities with east coast, South Island faunas, but in other respects the fish faunas are more similar in composition to those reported from the west coast of the South Island.

Gut analysis of *Gobiomorphus huttoni* and *Galaxias fasciatus* confirmed that they feed predominantly on benthic invertebrates and terrestrial prey items, respectively. Both species appeared to be opportunistic feeders and showed a low degree of prey selectivity.

One of the most distinctive features of the Stewart Island freshwater fauna is the absence or relative rarity of certain common mainland taxa. Among the fish, the Eleotridae is poorly represented with only two species, compared with six on the mainland. Furthermore, the torrent fish (*Cheimarrichys fosteri*), black flounder (*Rhombosolea retiaria*), and the alpine galaxiid (*Galaxias paucispondylus*) were not found. Brown trout (*Salmo trutta*) were also expected to be present given their widespread distribution on the mainland, but I am confident that they are absent. The invertebrate fauna is characterised by a paucity of Notonemouridae (Plecoptera), Conoesucidae (Trichoptera), and cased caddis in general, and the apparent absence of the Megalopteran *Archichauliodes*.

Another distinctive feature is the abundance, more diverse habitat utilisations, and/or less restricted distributions of some taxa on Stewart Island than in other parts of New Zealand. For example, giant kokopu (*Galaxias argenteus*), and banded kokopu (*G. fasciatus*) appeared to be more abundant, and the latter more widespread on Stewart Island. Furthermore, along with the red finned bully (*Gobiomorphus huttoni*), *G. fasciatus* occupies a greater diversity of habitats on the island. Thus, the bully occurs on sandy and stony beds, and the banded kokopu is common in mainstem reaches of large streams as well as the smaller tributaries where it mainly occurs on the mainland. Of the invertebrates, the isopod *Austridotea benhami* is commonly encountered in lowland, east coast streams of Stewart Island, whereas elsewhere in New Zealand it is almost unknown. *Chiltonia rivertonensis, Paraleptamphopus subterraneus, Hydrobiosella stenocerca, Austroperla cyrene* and species of Scirtidae also appear to be more common on Stewart Island than records suggest they are on the mainland,

In answer to the question, "Are Stewart Island stream faunas different from those found on the southern mainland today?" it is my

opinion that the answer is no, and that the differences found are probably no greater than the differences between the North and South Islands, or the east and west coasts of the South Island. Stewart Island stream communities are probably representative of those that occurred in many "pre-human-disturbance", lowland New Zealand streams few of which are still present on the mainland today. However, the island is unique because of the size, diversity and completeness of these communities and habitats, and because they are essentially free of adventive species. In particular, trout, macrophytes and Gastropoda (e.g., *Physa* and species of *Lymnaea* that are common elsewhere in New Zealand). Nevertheless, the very recent occurrence of chinook salmon (*Oncorhynchus tshawytscha*) emphasises the need for more comprehensive protection of the island's inland waters, other than that afforded by the island's reserve and conservation land status.

Scientifically and intrinsically, the island is extremely important if we are to increase our understanding of the effects of anthropogenic disturbances on the New Zealand biota. For example, the banded kokopu distribution data I collected, conflicts with the commonly held notion that it prefers small forested streams, and suggests that this species would have exhibited greater habitat diversity on the mainland prior to the introduction of trout. Stewart Island provides an ideal environment in which to carry out long-term investigations of factors such as behavioural interactions, home ranges, in-stream movements, population dynamics and breeding biology of native fishes, information that is sadly lacking for many species. Likewise, the diversity of physicochemically, and morphologically different streams and riparian vegetations type on the island means it is ideal for studies of longitudinal distributional patterns of benthic invertebrates.

In 1968, McDowall noted that conservationists seemed unaware that New Zealand possessed a freshwater fauna of great intrinsic interest and peculiarity, a point he reiterated 16 years later (McDowall 1984), while countering the statement of Imboden and Crooks (1977) that 'Birds... are New Zealands main indigenous wildlife.' Unfortunately, this type of insular view has also permeated the philosophies of many fisheries biologists, who have traditionally put more emphasis on the management of introduced acclimatised species rather than the conservation of native species. For example, in their submission on the draft inventories on wild and scenic rivers of national importance, Tierney et.al. (1982) gave

extensive coverage to acclimatised fish and some rivers were recommended because they contained rare or localised **introduced** species. At that time, Fisheries Research Division also considered there was little value in compiling even a tentative national list of rivers of scientific or biological importance based on their importance as native fish habitats (Tierney et.al. 1982). In part, this was because of a perceived paucity of biologically unmodified river systems, and only three lakes (Rotopounamu, Marion, and Christabel) have been deemed worthy of faunistic reserves status, where the release of animals or plants of any type is unlawful (McDowall 1984). Because of its largely pristine nature, Stewart Island provides an excellent opportunity to redress this apparent imbalance.

In 1984, McDowall listed six criteria that he felt were appropriate for fish reserves;

1. Naturalness of habitat
2. Size
3. Permanence of water
4. Access to the sea
5. Absence of exotic species
6. Absence from exploitation

The stream environments of Stewart Island fulfil all of these criteria, and only numbers 5 and 6 need discussion. Thus, although chinook salmon have been recorded in the Rakeahua River, they are probably very recent colonists originating from the Big Glory Bay salmon farms. Whether a self sustaining population will occur on the island in due course is unknown, but the history of salmonid introductions in New Zealand suggest it is unlikely. Nevertheless, their establishment should be discouraged, despite the likelihood that their impacts as transient freshwater inhabitants would probably be minor compared with the effects of trout. A self introduced and self sustaining Chinook salmon population would be unique in New Zealand, and it would be ironic if Stewart Island's freshwaters were protected because of this.

Point 6, the need for an absence of exploitation may seem facile, but permission has been given in the past to commercially eel the lower Freshwater and Rakeahua Rivers. Furthermore, as McDowall (1984) pointed out, 'the Fiordland National Park Board has openly discussed the question of approving commercial eeling, and at one stage permitted the removal of indigenous eels from park waters, as a means of protecting *introduced* salmonids'! Also, large scale whitebaiting does not occur on the island

at present, but given current prices it could become a problem in the future.

To conclude, I believe that Stewart Island freshwater systems should be protected because they represent some of the only large 'pristine' habitats that exist in New Zealand today. My study has revealed that an interesting fauna is present and that a number of its characteristics are those which are presumed to have been exhibited on the main islands of New Zealand prior to human settlement. However, this is only a baseline study, and should be used as a spring board for future research, and not be considered the definitive work.

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APPENDIX 1: *AUSTRIDOTEA BENHAMI* SALINITY TOLERANCE TEST

INTRODUCTION

In many Stewart Island stream systems, the isopod *Austridotea benhami* is restricted to the region at or just above the upper estuarine limits. This suggests that *A. benhami* may be a brackish water species that is only a recent colonist of freshwaters, and that the upper limit of its distribution in streams is caused by an intolerance of low salinity waters.

I tested the tolerance of *A. benhami* to a range of salinity conditions, and report the results of these tests here.

METHODS

Isopods were collected from a riffle in the Maori River about 30 m above the upper limit of sea water during high tide. Twenty individuals were placed in 400 ml polyethylene containers of water with salinities ranging from 0 % (distilled water) to 100 % sea water, within two hours of capture. Sea water was diluted with distilled water to give a range of concentrations (0, 5, 15, 25, 50, 75, 100 % seawater). Containers were aerated for 5 to 10 minutes every day, by bubbling air through each from a hose connected to the outlet valve of a scuba dive tank. Periodically, isopods were fed a variety of stream invertebrates. Dead isopods and uneaten prey were removed every eight or twelve hours for up to 10 days.

RESULTS

Results are summarised in Table 1 and show that mortality was low for the first four days at all salinities. Thereafter, greater mortality was recorded, especially in 0, 50 and 100 % sea water.

DISCUSSION

Setting aside the rather basic conditions underwhich this work was carried out in the field on Stewart Island and the many problems associated with physiological tolerance tests, it is nevertheless, apparent that *A. benhami* is euryhaline and capable of surviving in pure sea water and deionised freshwater for moderate periods. The ability to

tolerate saline media up to and including full strength sea water is a feature more typical of a brackish-water species than a freshwater one (Croghan and Lockwood 1968). High mortalities recorded in distilled water also suggest *A. benhami* is a brackish-water species.

The results of these tests support the contention that the upper limit of *A. benhami* at least in Maori River is a consequence of an intolerance of low salinity.

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Table 1. Numbers of *Austridotea benhami* surviving over time in a range of sea water concentrations (range 100 % distilled water to 100 % sea water).

		Salinity (%)						
		0	5	15	25	50	75	100
Days	1	20	20	20	19	19	19	20
	2	19	19	18	19	18	16	19
	3	18	19	18	19	17	16	17
	4	18	18	18	19	17	16	15
	5	17	18	18	19	16	16	10
	6	17	18	18	19	16	16	10
	7	11	17	17	19	10	16	9
	8	10	16	17	19	10	16	9
	9	10	16	17	19	10	16	9
	10	10	13	17	19	9	16	8